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AFGL-TR-88-0328

Evaluation of the AFGL Cloud Simulation Models Using Satellite Data

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December 1988

Final Report
1 April 1985-15 October 1988

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
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Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S) AFGL - TR - 88 - 0328
6a. NAME OF PERFORMING ORGANIZATION Research and Data Systems, Corp. 6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION Air Force Geophysics Laboratory
6c. ADDRESS (City, State, and ZIP Code) 7855 Walker Drive Greenbelt, MD 20770	7b ADDRESS (City, State, and ZIP Code) Hanscom AFB Massachusetts 01731-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F19628-85-C-0007
8c. ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
62101F	6670	09	AN

11 TITLE (Include Security Classification)

Evaluation of the AFGL Cloud Simulation Models Using Satellite Data

12 PERSONAL AUTHOR(S)
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13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final Report	FROM 4/1/85 TO 10/15/88	1988 December	166

16. SUPPLEMENTARY NOTATION

*Analytic Sciences Corp., 55 Walkers Brook Dr., Reading, MA 01867

17. COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Sky cover distributions; cloud distribution; sample size determination; Monte Carlo Simulation; cloud detection; sky cover database; model validation

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This report presents the results of the validation of three empirical models of the distribution of the total sky cover over lines and areas; the Burger Area Algorithm (BAA), Burger Line Algorithm (BLA) and the Gringorten Interval Algorithm (GIA). The generation of a sky cover database from satellite imagery, the determination of appropriate sample size and the determination of goodness-of-fit error bounds are discussed. The models are run, and their output compared to empirical cloud cover distributions. Goodness-of-fit statistics are used to evaluate the results of the models. Conclusions and recommendations concerning the utility of the models are presented. [illegible] Atmospheric models, [illegible] analysis, Spatial distribution.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Oliver Muldoon, Capt, USAF	22b TELEPHONE (Include Area Code) (617) 377-5957 22c. OFFICE SYMBOL AFGL/LYA

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

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1. BACKGROUND

The Air Force requires a cloud simulation model to support the design, development, and employment of tactical and strategic weapon systems that are sensitive to cloud cover and associated weather phenomena. For example, an electro-optical system may depend on having a cloud-free line of sight in order to operate successfully. Also, cloud cover can be used by friendly forces to defeat threat systems. To meet these needs, the Air Force Geophysical Laboratory (AFGL) and the Air Weather Service (AWS) developed a number of empirical and statistical cloud models used to simulate system performance during development and as tactical decision aids to support deployed systems.

AFGL's models currently estimate the cumulative distribution functions (CDF's) of cloud cover along horizontal lines of different lengths and over horizontal areas of different sizes. The CDF is the basis for presenting the probability of specific cloud covers in this report. The CDF for any cover value (e.g., 40% cloud cover) is the probability of that amount or less of fractional coverage. AFGL also has an algorithm to estimate the CDF's of maximum length of clear and cloudy intervals along longer lines of travel. These models are based on the Boehm Sawtooth Wave (BSW) model and require only two point statistics (mean clear (Po); and scale distance (r)) as input. The mean clear figure reflects statistically the percent of time no cloud is present above any given surface point (i.e., no cloud exists along a geocentric ray through a point on the surface). This should be equal to the mean percentage of clear sky present in the viewing dome of any station within the area to which Po is assigned. Po is determined as unity minus the mean cloud cover for that location. Mean clear is assumed to be the same for all areas and lines within the region for a given season and time of day. It is a location parameter for the coverage distribution.

The scale distance is a measure of the horizontal persistence of cloud cover, also known as the sky dome scale distance (i.e., the degree to which features at one location are correlated to those observed at other, nearby locations). For example, if a given region, say a state, is either entirely clear or entirely cloudy, the scale distance for a point in that state would be large. Conversely, if small isolated patches of cloudiness were always present randomly throughout the state, the scale distance would be small, because cloudiness at one location would convey little information about other nearby locations. The scale distance is the shape parameter for the coverage distribution. While the mean cloud cover gives an accurate long-term description of cloud amount, the scale distance is necessary to provide insight into the nature and extent of that cloud cover.

Most real locations will fall between the hypothetical extremes of a location which is always either clear or overcast, and a location which is always partly cloudy. The ability of a model to simulate cloud climatologies near both extremes will determine its ultimate usefulness and general applicability.

The BSW is an algorithm for economically generating random fields which may be correlated in space and time. The AFGL models were developed by fitting curves to CDF's from a large synthetic database derived by BSW Monte-Carlo simulation. The AFGL models agree well with the developmental data, but the extent of agreement with observational (satellite-based) data had to be determined.

Research and Data Systems (RDS) and its subcontractor, The Analytic Sciences Corporation (TASC) evaluated the AFGL statistical cloud modeling algorithms, known as the Burger Area Algorithm (BAA), the Burger Line Algorithm (BLA), and the Gringorten Interval Algorithm (GIA), by comparing theoretical model-based CDF's to observational (satellite-based) CDF's of cloud cover using statistical goodness-of-fit tests.

The BAA and BLA models were developed at AFGL by Burger and Gringorten and are described in their Technical Report (Ref. 1) which discusses the algorithms' equations and applications to sky cover estimation. The BAA is an algorithm estimating the probability pA that the areal fractional cloud cover cA is less than or equal to a threshold areal coverage CA, given the area A, the scale distance r, and a probability p0 that a point on the surface is not cloud covered. Similarly, the BLA is an algorithm estimating the probability pL that the lineal fractional coverage cL, is less than or equal to a threshold lineal coverage CL, given a line length L, scale distance r, and probability p0 that a point on the surface is not cloud covered. Note that for a point on the surface p0 is equivalent to the mean clearness at a point and 1-p0 is the mean sky cover, a statistic commonly available from various climate records. The BAA and BLA are essentially curve fits to data samples generated by multiple runs of the Boehm Sawtooth Wave (BSW) model (Ref. 1).

The clear GIA is an algorithm which estimates the probability pI that the longest clear line interval is greater than or equal to a line threshold interval I, given line length L, scale distance r, and mean clearness P0.

The following example is given to help illustrate the concept of the GIA:

Given: (algorithm input): Po = 0.33 (mean clear)
r = 5.484 km (scale distance)
L = 10 km
I = 1 km intervals from 1 to 10 km
Number of observations in dataset = 100

Find: (algorithm output): The probability that the longest clear interval is at least I km long.

Results:

I (km)	cum pI	Individual Probability Frequency	Cumulative Frequency
0	1.0	0.642 x 100 - 64.2	100.0
1	0.358	0.016 x 100 = 1.6	35.8
2	0.342	0.004 x 100 = 0.4	34.2
3	0.338	0.001 x 100 = 0.1	33.8
4	0.337	0.005 x 100 = 0.5	33.7
5	0.332	0.002 x 100 = 0.2	33.2
6	0.330	0.001 x 100 = 0.1	33.0
7	0.329	0.002 x 100 = 0.2	32.9
8	0.327	0.002 x 100 = 0.2	32.7
9	0.325	0.002 x 100 = 0.2	32.5
10	0.323	0.323 x 100 = 32.3	32.3

From the table above it can be seen that the probability (pI) is a cumulative probability distribution increasing from the bottom (i=10) to the top (i=0). From the individual frequencies it is evident that the first (0 km) interval will always be 1.0 and the last interval (10 km) will have the lowest cumulative frequency. It can be seen that the probability that the entire line is cloudy (i.e., no clear interval greater than or equal to 1 km) exists is 0.642. The probability that the entire 10-km length is clear is

0.323. The intermediate intervals have very small individual probabilities.

2. STATEMENT OF WORK

The Statement of Work is provided as a reference point from which satisfactory performance of the contract can be inferred. The RDS/TASC team used bispectral GOES imagery to test the validity of the AFGL algorithms by empirically deriving relationships between cloud cover, reference areas, line lengths and intervals along lines of travel, and comparing these to relationships predicted by algorithms. In order to accomplish the objective, there were four major study tasks:

2.1 SITE SELECTION (TASK 1)

RDS,TASC, and AFGL selected three representative sites based on the following criteria: availability of Revised Uniform Summaries of Surface Weather Observations (RUSSWO's), uniformity of surface characteristics, type of cloud cover distribution, period of record of the RUSSWO's, and availability of satellite data. Ft. Riley, KS, Rickenbacker AFB, OH, and Key West, FL, were chosen as sites.

2.2 TOTAL CLOUD COVER CLIMATOLOGY (TASK 2)

2.2.1 Satellite Data Base Selection

GOES, the NOAA Polar Orbiters (NPO), and DMSP data were considered as viable candidates using the following criteria: period of record, continuity of record, daily frequency, viewing geometry, resolution, data format, cost to acquire, and cost to process and analyze. GOES data were selected and the highest resolution visible and IR digital data were acquired from the Satellite Data Service (SDS) of NOAA. The dataset consists of five consecutive years of two season (Winter, Summer), two times (15Z, 18Z) per day, for 360-km square boxes centered on the test sites. SDS agreed to provide these data at a greatly reduced unit cost due to the large size of the order. It was delivered on eight 6250-bpi computer tapes. Two times per day were selected to ensure a variety of cloud distribution types. A 5-year period of record was chosen on the basis of an analysis of statistical significance.

2.2.2 Selection of Reference Areas and Lines

The Request for Proposal (RFP) specified that cumulative total cloud cover frequencies be derived for five concentric areas centered on the test sites ranging from an area of 100 km^2 and including an area of 2424 km^2, and along two horizontal lines (north-south and east-west) passing through the sites. Additional areas were 1000, 10,000 and 100,000 km^2. The 2424 km^2 area approximates a nominal surface observer's viewing area.

2.2.3 Cloud Detection Methodology

An automated cloud detection algorithm was used based on both visible and IR brightness thresholds. This was more accurate and more economical than manual interpretation of each image.

2.2.4 Software Development

The software required was developed to read the GOES tapes, rectify the images, construct background brightness fields, automatically detect cloud cover, compute cloud amount on areas and lines, check QA alarm criteria, manually correct images, and compute required statistics.

2.2.5 Quality Assurance

Each cloud cover estimate was tested with the IR data and simultaneous surface data reports. The latter data provide a unique capability to check backgrounds (e.g., snow cover) and to challenge the automatic cloud cover estimates with surface cloud observations. Suspect imagery was flagged by the TASC computers where qualified analysts either accepted, modified, or rejected the automatic estimates and altered the data base accordingly.

2.2.6 Cumulative Cloud Cover Frequencies

The quality checked files of cloud cover estimates were summarized as cumulative frequencies of cloud cover in twenty cells. Distributions for each of five concentric areas and along various length perpendicular line segments passing through each test site were derived two times per day for five years of Winter and Summer months.

2.3 EVALUATION OF AFGL MODEL OUTPUT (TASK 3)

Various proven statistical tests were used to determine whether or not cloud cover distributions produced by the AFGL model were from the same statistical population as the calibrated satellite-derived cloud distributions. These tests accounted for the initial uncertainties due to limited data and the precision of the analysis algorithm.

2.4 RECOMMENDATIONS (TASK 4)

The RDS/TASC team stated explicitly the uncertainties, limitations, and confidence in the results of this study. Specific recommendations were made for additional data and tests needed in the future to reduce uncertainty and raise confidence in the analysis results.

2.5 REPORTS

The RDS/TASC team established an internal reporting system that ensures the prompt delivery of quarterly and final reports required by the RFP.

3. WORK PERFORMED

3.1 SITE SELECTION

The RDS/TASC Team worked with AFGL to select three representative sites based on the following criteria:

- Cloud cover distributions should be significantly different from one area to another
- Cloud climate in each area should be as spatially homogeneous as possible
- Horizontal distance from each area to the GOES subpoint should be as small as practical
- Each area should be centered on a surface reporting station associated with a RUSSWO climate summary
- Surface observations coincident with the image samples should be available.

Based on a survey of available RUSSWO's and application of the other criteria, the study team investigated three areas centered on Ft. Riley, KS; Rickenbacker AFB, OH; and Key West, FL (the area around Key West is somewhat offset in order to minimize inhomogeneities created by the Florida mainland). Each area is a square approximately 316 km x 316 km. Surface reports in the USAF/AWS DATSAV format are available coincident with the image sample period.

3.2 TOTAL CLOUD COVER CLIMATOLOGY

3.2.1 Determining Image Sample Size

A simple procedure for determining an acceptable image sample size is the subject of Appendix F of this report. A more sophisticated procedure is described in AFGL-TR-88-0116. Based on these procedures, it was shown that a satisfactory validation could be performed in each area using sample sizes of 450 or more images for each time of day and season. Consequently, five years of bispectral imagery acquired twice per day during the winter and summer months from 1979 through 1983 were used for a grand total of 5460 subscenes. See Appendix F and AFGL-TR-88-0116 for a more detailed discussion of the sample size selection determination.

3.2.2 Selection of Reference Areas and Lines

In this study, five areas (10^2, 32^2, 50^2, 100^2, and 316^2 km^2) for the BAA algorithm, 10 lines (five east-west, five north-south of 10, 32, 50, 100, 316 km) for the BLA algorithm, and two runs (one for cloudy intervals, one for clear intervals for each of five lines, 10, 32, 50, 100, 316 km) for the GIA algorithm. All reference areas and lines were run for the twelve files (three locations, two seasons, and two times of day) producing model CDF's and satellite-based CDF's for all areas and lines.

3.2.3 Acquisition of GOES Data

The visible and IR subscenes were acquired from NESDIS in digital form in the highest resolution and gray scale available from the archives. Visible images have 64 gray shades and a resolution of about 1 km; IR images have 256 gray shades and a resolution of about 8 km.

3.2.4 Developing Automated Cloud Detection and Analysis Programs

The RDS/TASC team developed an automated bispectral procedure to detect clouds on GOES imagery, compared cloud cover with observed ground truth, rejected suspect images for manual interactive evaluation, and extracted areal and lineal database parameters. Appendix A summarizes the logic of this process. Approximately 12 percent of the imagery failed the quality control checks and was rejected.

All phases of the procedure were run on an Alliant FX-8 mini supercomputer using a modified version of the TASC Interactive Image Processing System (TIIPS). The processing of each image and insertion of required statistical values into the database required 24 seconds per image on the Alliant FX-8.

3.2.5 Creation of the Cloud Cover Database

Creation of the cloud cover database involved running all of the 5460 subscenes through the database software programs and building a dataset in a format suitable for processing. After the data were read from the tape, a conversion from digital values to image format was made. Then, the subscenes (316 km by 316 km) for the desired site were extracted, the visible and IR images were registered, and the set was registered to the previous day's images. This process was repeated for a predetermined number of days (typically one month). Next, a minimum background map based upon five successive days of data was computed for both the visible and IR images. This map represented an estimate of the scene when no clouds are present. The peak (or mode) value in the background map was determined and subtracted from the images over the same five-day period. The resultant images were thresholded at empirically derived values (10 to 15) to account for image noise. The cloud statistics for each of the five areas and line lengths were computed. A description of the algorithms used for image processing is given in Appendix A, along with a description of the delivered dataset output files in Appendix B.

3.2.6 Generation of Mean Clear and Scale Distance Parameters

The mean clear, Po, was computed directly from the satellite-derived cloud distributions. It was computed using the largest (100,000 km^2) area because this area contained the most data and, therefore, the most information. Using the largest area was implicit in our adequate sampling-size determination (Section 3.2.1). Given the area size, Po, and the satellite-derived cloud CDF's, scale distance was calculated using the AFGL scale distance algorithm. This may be thought of as an inverse BAA, using the cloud distribution to estimate the scale distance. Although Po and r are computed from the largest area, they are assumed to apply to all lines and areas. It should also be noted that since Po and r are computed from the data on which the model will be tested, that test does not constitute an independent test.

3.3 EVALUATION OF AFGL MODEL OUTPUT

3.3.1 Overview of the Evaluation Process

The evaluation process begins with running the algorithms for all permutations of site, season, time of day, line or area size using the mean clear and scale distance parameters presented in Table 1. These results were binned and compared to the original satellite-derived cloud distributions using goodness-of-fit tests. The tests used were K-S, G, and Chi-squared. The results are summarized in Tables 1 through 7 in Appendix D. The critical values for determining pass/fail were derived in the simulation studies (Section 3.3.4).

Table 1
Summary of Scale Distance (r) and Mean Clear Sky Cover (Po)
Used in BLA, BAA, and GIA Models

Site	Season	Time	r (km)	Po
Ohio	Winter	15Z	5.484	0.32484
Ohio	Winter	18Z	6.141	0.29250
Ohio	Summer	15Z	5.648	0.47418
Ohio	Summer	18Z	3.708	0.38175
Kansas	Winter	15Z	7.366	0.54400
Kansas	Winter	18Z	6.617	0.47299
Kansas	Summer	15Z	6.348	0.58318
Kansas	Summer	18Z	5.767	0.54624
Florida	Winter	15Z	4.695	0.47015
Florida	Winter	18Z	4.613	0.46632
Florida	Summer	15Z	2.656	0.61745
Florida	Summer	18Z	2.799	0.57729

3.3.2 Cloud Cover Database Format

Five years of GOES Data (VIS and IR) was received on floppy disc. The data was transferred to the Leading Edge hard disc, and combined so all five years of data were contained in each of the 12 files (3 sites x 2 seasons x 2 times). A summary of the data files follows:

1. 15z Ohio Winter (LCK)
2. 15z Ohio Summer (LCK)
3. 18z Ohio Winter (LCK)
4. 18z Ohio Summer (LCK)
5. 15z Kansas Winter (FRI)
6. 15z Kansas Summer (FRI)
7. 18z Kansas Winter (FRI)
8. 18z Kansas Summer (FRI)
9. 15z Florida Winter (EYW)
10. 15z Florida Summer (EYW)
11. 18z Florida Winter (EYW)
12. 18z Florida Summer (EYW)

The data contains GOES (satellite-based) CDF's from 5 years of visible (VIS) and infrared (IR) data from each site (LCK, FRI, EYW), each season (Winter and Summer), and each time (15z, 18z). The CDF's for the BLA, BAA and GIA were all from the input data file. Appendix A provides a more detailed description on the image processing algorithms used in the study.

3.3.3 Data Preparation and Binning: BLA and BAA

The model CDF's were originally based on 22 separate cloud fraction bins from 0.0 (completely clear) to 1.0 (completely overcast) in 0.05 increments and are summarized in Table 2. However, due to unreliable data the first two bins and the last two bins (21 and 22) were combined to yield 20 cloud fraction bins (see Table 2). This binning process improved the models performance considerably. In addition to binning the data by 20 cloud fraction bins any model bin with a frequency of less than 5 was combined with the next model bin frequency until the value was at least 5. The corresponding GOES (satellite-based) bins were combined to ensure the same number of model-based and satellite bins for the statistical tests (CHI. SQ. and G tests). The BLA program produced a total of 120 CDF's. The 120 CDF's consist of:

a. 5 east-west lines + 5 north-south lines = 10 lines

b. 3 sites x 2 seasons x 2 times = 12 files

c. 10 lines x 12 files = 120 CDF's

The BAA Program produced a total of 60 CDF's:

a. 5 areas (10, 32, 50, 100, 316 km^2) = 5 areas

b. 3 sites x 2 seasons x 2 times = 12 files

c. 5 areas x 12 files = 60 CDF's

Table 2
Cloud Fraction Binning Process Used To Produce CDF's

Bin	Cloud Fraction
* 1	0.0
* 2	0.0 - 0.05
3	0.05 - 0.10
4	0.10 - 0.15
5	.15 - 0.20
6	.20 - 0.25
7	.25 - 0.30
8	.30 - 0.35
9	.35 - 0.40
10	.40 - 0.45
11	.45 - 0.50
12	.50 - 0.55
13	.55 - 0.60
14	.60 - 0.65
15	.65 - 0.70
16	.70 - 0.75
17	.75 - 0.80
18	.80 - 0.85
19	.85 - 0.90
20	.90 - 0.95
* 21	.95 - 1.00
* 22	1.00

* Combined Bins: yielding 20 total bins

An example of the output generated during the evaluation process is given in Appendix C.

3.3.4 Simulation Studies

The purpose of the simulation studies was to determine the critical values for the goodness-of-fit hypothesis tests. Exact critical values were unknown because of violations of requirements for the goodness-of-fit tests. The procedure to perform the simulation studies is given in Appendix H.

3.3.5 Isotropy Tests

An assumption of the BAA, BLA, and GIA algorithms is that the sky cover is isotropic within the area of application of the algorithm. To test that assumption for the datasets used in this project, two statistical tests of isotropy were performed. At any site, if sky cover is isotropic, then sky cover distributions along perpendicular lines should be similar. The random nature of cloud fields precludes the likelihood that the distributions will be identical. However, if sky cover is significantly anisotropic, then we should be able to detect statistically (and practically) significant differences between the distributions of sky cover along east-west and north-south lines.

The data sets employed in these tests included distributions of three pairs of variates accumulated over the longest (316 km) horizontal (east-west) and vertical (north-south) lines:

- fractional sky cover (20 cells, 0.0 to 1.0)

- longest clear run (16 cells, 0 to 320 km)
- longest cloudy run (16 cells, 0 to 320 km)

In all, twelve data sets were obtained by taking all combinations of three sites (Florida, Kansas, and Ohio), two seasons (winter and summer), and two times a day (15Z and 18Z). Sample sizes ranged between 298 and 415.

Appendix G presents histograms for each pair of distributions. The histograms facilitate graphical comparisons of the distributions. Table 3 summarizes those test results.

Table 3
Summary of Test Results

	1500 GMT						1800 GMT					
	COVER		CLEAR		CLOUDY		COVER		CLEAR		CLOUDY	
	KS	t	KS	t	KS	t	KS	t	KS	t	KS	t
FLORIDA												
SUMMMER	**	**	**	--	--	--	**	**	**	**	**	**
WINTER	**	**	**	**	--	--	**	**	**	**	--	*
KANSAS												
SUMMER	--	--	--	--	--	--	--	--	--	--	--	--
WINTER	--	--	--	--	--	--	--	--	--	--	--	--
OHIO												
SUMMER	--	--	--	--	--	--	--	--	--	--	--	--
WINTER	--	--	--	--	--	--	--	--	--	--	--	--

Key: "--": anisotropy is not significant
" *": anisotropy is significant at the 0.05 level
"**": anisotropy is significant at the 0.01 level

We see that there is no evidence whatever of anisotropy at the Kansas and Ohio sites. Florida is different. The evidence for anisotropy is overwhelming in three of the four Florida data sets.

In the fourth data set there is a suggestion of anisotropy. We examined the Florida imagery to assure ourselves that the discovered anisotropy was, in fact, a natural phenomenon.

3.3.6 Goodness-of-Fit Tests

Three statistical goodness-of-fit tests were run comparing theoretical (model-based) CDF's to empirical (satellite-based) CDF's for the BLA, BAA, and GIA models. Two of the tests, the Kolmogorov-Smirnov (K-S) Test and the G-Test, each has unique advantages. The third test, the CHI-squared test, was included because it is the traditional goodness-of-fit test. For a more detailed description of the goodness-of-fit tests and equations for each test see Appendix E.

a. BLA - Tables 1-3 in Appendix C contains a complete list of the K-S, G and CHI-squared results for the BLA algorithm. The tables contain the critical values and actual values generated from the tests for each line (horizontal and vertical) from all 12 files. Note, that the critical values listed in the tables for all three tests were derived from the simulation studies. These results show that:

1. All the tests yielded similar results.

2. The tests failed in the majority of cases.

3. The tests that passed were for the longest lines (316 km).

4. The Ohio and Kansas tests were better than the Florida results.

5. The Florida tests failed for all lines and all areas.

6. The largest margins of error were found in the Florida cases.

7. Some tests yielded marginal results (i.e., slightly large actual test statistics).

8. The marginal results were also only found for the longest lines.

The following list summarizes the K-S tests that passed or were marginal (within upper and lower bounds or critical values).

15 Ohio Summer (horizontal) 316 km Pass

15 Kansas Winter (horizontal) 316 km Pass

15 Kansas Winter (horizontal and vertical) 316 km Pass

18 Kansas Summer (horizontal) 316 km Marginal

The results were also summarized in terms of (1) site, (2) line length, (3) season, and (4) time to determine if any of these parameters played a significant role in the results. Table 4 summarizes the results. It was found that site and line length are significant parameters and affect model results.

Table 5 summarizes the goodness-of-fit statistics in terms of a pass, marginal, or failure basis for both horizontal and vertical lines for all 12 files and all 5 lines. Detailed tables which show actual CHI-squared, G, and K-S statistics and critical values are given in Appendix D.

b. <u>BAA</u> - The results from the BAA statistical goodness-of-fit tests are similar to those from the BLA algorithm. Model-based CDF's were compared to satellite-based CDF's for 5 areas (10, 32, 50, 100, 316 km^2) and 12 files yielding 60 BAA CDF's. Table 6 below summarizes the BAA test results in terms of pass/fail or marginal basis. Marginal passes were those values that fell within the upper and lower bounds of the critical values generated in simulation studies. The results are very similar to the BLA results in that the only tests that pass or are marginal are for the largest area (316 km^2) at the Ohio

Table 4
BLA K-S Test Summaries (# Passes or Marginal)

A. By line length:

Size	Passes	Possible (Passes)	
10	0	24	
32	0	24	Line length
50	0	24	is important;
100	0	24	316 km line
316	7	24	does best
	7	120	

B. By site:

Site	Passes	Possible (Passes)	
Ohio	2	40	
Kansas	5	40	Site is
Florida	0	40	important; Ohio
	7	120	and Kansas do
			better

C. By Season:

Season	Passes	Possible	
Winter	4	60	Season is <u>not</u>
Summer	3	60	important
	7	120	

D. By Time:

Time	Passes	Possible	
15Z	3	60	Time is <u>not</u>
18Z	4	60	important
	7	120	

Table 5
BLA Test Results

				East-West			North-South		
Site	Season	Hr	Size	KS	G	CHI^2	KS	G	CHI^2
FL	W	15	10	F	F	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	F	F	F	F	F	F
FL	W	18	10	F	F	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	F	F	F	F	F	F
FL	S	15	10	F	F	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	F	F	F	F	F	F

Table 5 (continued)
BLA Test Results

Site	Season	Hr	Size	East-West KS	East-West G	East-West CHI^2	North-South KS	North-South G	North-South CHI^2
FL	S	18	10	F	F	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	F	F	F	F	F	F
KS	W	15	10	F	M	M	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	P	P	F	F	F	F
KS	W	18	10	F	M	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	P	P	P	P	M	M
KS	S	15	10	F	F	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	M	F	F	F	F	F
KS	S	18	10	F	F	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	M	F	F	F	F	F
OH	W	15	10	F	F	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	M	F	F	F	F	F
OH	W	18	10	F	F	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	M	F	F	F	F	F
OH	S	15	10	F	F	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	P	F	F	F	F	F

Table 5 (continued)
BLA Test Results

Site	Season	Hr	Size	East-West KS	East-West G	East-West CHI^2	North-South KS	North-South G	North-South CHI^2
OH	S	18	10	F	F	F	F	F	F
			32	F	F	F	F	F	F
			50	F	F	F	F	F	F
			100	F	F	F	F	F	F
			316	F	F	F	F	F	F

Table 6
BAA Goodness-of-fit (GOF) Results

Site	Season	Hr	Size	K-S	G	X
FL	W	15	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	F	F	F
			316	F	F	F
FL	W	18	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	F	F	F
			316	F	F	F
FL	S	15	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	F	F	F
			316	F	F	F
KS	W	15	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	M	F	F
			316	F	P	P
KS	W	18	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	M	F	F
			316	P	P	P
KS	S	15	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	F	F	F
			316	P	M	M

Notes

1. F=Fail GOF Test
   P=Pass GOF Test
   M=Marginal Pass GOF Test

2. No test passed with Florida data

Table 6 (continued)
BAA Goodness-of-fit (GOF) Results

Site	Season	Hr	Size	K-S	G	X
KS	S	18	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	F	F	F
			316	P	P	P
OH	W	15	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	F	F	F
			316	F	F	F
OH	W	18	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	F	F	F
			316	P	P	P
OH	S	15	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	M	F	F
			316	P	P	P
OH	S	18	10	F	F	F
			32	F	F	F
			50	F	F	F
			100	M	F	F
			316	P	P	P

and Kansas sites. Once again all Florida cases fail for all areas.

The BAA results were also summarized (Table 7) in terms of 1. site, 2. area, 3. season, 4. time; to determine which of these 4 parameters played a significant role in the statistical results.

Table 7
BAA Results Summaries (Pass/Fail)

a. by Area:

Size	#Passes	Possible (Passes)
10^2	0	12
32^2	0	12
50^2	0	12
100^2	4	12
316^2	7	12
	11	60

Area is significant

b. by Site:

Site	#Passes	Possible Passes
Ohio	5	20
Kansas	6	20
Florida	0	20
	11	60

Site is significant

c. by Season:

Season	#Passes	Possible Passes
Winter	5	30
Summer	6	30
	11	60

d. by Hour:

Hour	#Passes	Possible Passes
15Z	5	30
18Z	6	30
	11	60

c. GIA Test Results: Three Goodness-of-fit statistical tests were run comparing theoretical (model-based) distributions to empirical (satellite-based) distributions for 2 runs (clear and cloudy), over all 5 lines (10, 32, 50, 100, 316km); and 12 files (3 sites x 2 seasons x 2 times) for a total of 120 test distributions (2 x 5 x 12 = 120). The K-S Test, G-Test, and CHI-squared test results are listed in Appendix D. The simulation studies which generate the critical values were only run for the BLA and BAA algorithms. No critical values were available for the KS-Tests or G-

Tests. However, standard statistical tables were consulted for a rough estimate of the CHI-squared critical values. A complete table of the actual K-S, G, and CHI-squared statistics for GIA is supplied in Appendix D. Note that the CHI-squared critical values are only estimates from CHI-squared tables. The results indicate that the vast majority of the distributions fail the CHI-squared tests. Only 3 distributions passed, those were:

1. 15Z Ohio Winter clear run at 10 km
2. 15Z Ohio Winter cloudy run at 10 km
3. 18Z Ohio Winter clear run at 10 km

Contrary to the results from the BLA and BAA only the distributions from the shortest lines (10 km) pass the Tests, and only Ohio Winter files pass the Tests. All other files fail. As in the BAA and BLA results the Florida distributions fail the Tests by the widest margins. An example of the output from the GIA algorithm and the GIA algorithm itself is given in Appendix C.

3.3.7 Conclusions

In general, our results indicate that the statistical tests failed for the majority of lines and areas used in this study. In summary, some of the explanations for the poor results are: 1) the models were positively biased for extremes of cloudiness (100%

clear, 100% overcast), and negatively biased for cloud fractions between 5% and 95%; 2) there is evidence for mixed distributions in Florida, while the model always assumes single distributions; 3) clouds in Florida might be anisotropic while the model assumes isotropic clouds; 4) the scale distance parameter was determined for the longest line and largest area and applied to all the other lines and areas; and 5) some of the distributions were nonmonotonic (i.e., cumulative frequencies became negative) indicating model inaccuracies in certain situations. The remainder of this section describes these 5 explanations in more detail.

a. <u>Model Biases</u>: In general, the model overpredicts extremes of cloudiness (100% clouds (overcast), 0% clouds (clear), and underpredicts cloudiness between 5% to 95%. This is very evident after visual analysis of the histograms presented in Appendix I.

b. <u>Evidence for mixed distributions for Florida Datasets</u>: It was found that the model did not fit any of the Florida datasets well. The 316 km^2 area should have fit well because it was used to derive the model parameters. Two possibilities for this result are: 1) the scale distance algorithm failed, and 2) the BAA is not capable of reproducing the 316 km^2 Florida distributions. An example of the empirical and model distributions for the 18Z Florida winter case is given in the histograms below. The histograms present a plot of percent frequency versus percent cloud coverage (bins) for each of the five areas from the 18Z Florida winter case. The plot for the 316 km^2 area clearly indicates the large difference between the model frequency (histograms) and empirical (bar lines), frequency especially for the smaller cloud fraction bins (i.e., small percent coverage). Appendix I contains the histograms for all of the BAA distributions (12 files) and all of the BLA distributions (12 files). Visual analysis of these distributions confirms the poor fit in the Florida cases, especially for the completely cloudy and completely clear bins (percent coverages). The histograms show spikes at the 100% coverage (completely cloudy bin) for the Florida data sets. The histograms also show that both the BLA and BAA are almost always positively biased (i.e., model predicted greater than observed frequency) for the extremes of fractional cloud cover (100% clear, 100% overcast). This provides more evidence that the models cannot reproduce the 316 km^2 Florida distributions. A possible explanation is that there is a mixture of distributions present. A recommendation for future work is to adapt the model fitting process to accommodate easily separated mixtures (such as the Florida datasets). This should enhance model performance in Florida.

c. Anisotropic Data in Florida: One of the major assumptions of the AFGL models is that clouds are isotropic within the area of application. However, in nature, especially in Florida, this may not be true. Cloudiness in Florida is often aligned in preferred directions (i.e., parallel to the coast) where convection is likely, thus negating the assumption of isotropy.

d. Determination of Scale Distance: Considerable effort was spent deciding which scale distance algorithm was appropriate for our study. After consultation with AFGL we decided to use the AFGL version of the scale distance algorithm. This is important because the BAA algorithm was embedded within the AFGL scale distance algorithm. Another important point is that we determined the scale distance for the longest line and largest area, and applied that scale distance to the other lines and areas to determine the model distributions for those lines and areas (see Section 3.2.6). Naturally, one would expect to get the best results for the longest lines and largest areas, due to this procedure. Our statistical tests confirm the result. A suggestion for future work may be to run the scale distance algorithm for shorter line length and see if the new scale distance improves the results for that particular line.

e. <u>Nonmonotonic Distributions</u>: In certain situations (i.e., shortest area, 100 km^2) the model produced negative frequencies. The cases where this occurred were:

1. Florida Winter 15Z
2. Florida Winter 18Z
3. Florida Summer 18Z
4. Ohio Summer 18Z

This nonmonotonic tendency may suggest model shortcomings for the shorter lines. Our results indicate that there were larger differences in model CDF's versus satellite CDF's for the shorter lines. An example of the nonmonotonic cumulative frequency is shown below for the 18Z Florida Winter Case (100 km^2 area):

Cloud	Cumulative Model Values		Individual
Bin	Percent	Cum. Model Frequency	Model Frequency
1	.448*357(#OBS)=160.08		160.08
2	.457	163.14	3.197
3	.454	162.07	-1.037
4	.452	161.36	-1.038
5	.458	163.51	2.271
6	.464	165.65	2.275
7	.464	165.65	-0.225
8	.463	165.29	-0.225
9	.465	166.01	0.598
10	.466	166.36	0.599
11	.468	167.08	0.599
12	.470	167.79	0.599
13	.469	167.43	-0.225
14	.468	167.08	-0.225
15	.475	169.58	2.280
16	.481	171.72	2.282
17	.478	170.65	-1.044
18	.475	169.58	-1.044
19	.484	172.79	3.216
20	.516	184.21	184.21

The BAA model returned the cumulative percentages for each cloud fraction bin, which were then converted to cumulative frequencies by multiplying the percentages by the number of GOES observations for the 18Z Florida Winter file (357). Finally, individual model densities for each bin are computed and listed.

4. RECOMMENDATIONS

The RDS/TASC team has evaluated the AFGL statistical cloud algorithms (BAA, BLA, and GIA) using observed data from the GOES satellite. Three statistical tests (Chi-squared, G, and K-S) were run to determine the goodness-of-fit between model CDF's and observed CDF's for 12 files described in the text. In our evaluation procedure the statistical tests had to be modified somewhat because the two data sets were not totally independent. The model input statistics (po and r) were generated from the GOES data used in this study. Due to the fact that the two data sets were not totally independent, published tables of critical values for the goodness-of-fit tests could not be used. The critical values (BAA and BLA) were generated by Monte Carlo simulation. In general the statistical tests failed (i.e., actual value > critical value) for the majority of files (lines and areas).

In summarizing the results, the following was found:

1. In general, the model overpredicts extremes of cloudiness (100% clouds (overcast), 0% clouds (clear), and

underpredicts cloudiness between 5% to 95%. This is very evident after visual analysis of the histograms presented in Appendix I.

2. In some instances (at 10 km line and 10 km^2 area) the models tended to be nonmonotonic (i.e., negative frequencies). The GIA algorithm also had some nonmonotonic values for the longer (100 km and 316 km) lines.

3. The Florida distributions yielded the worst results (i.e., failed the goodness-of-fit tests by the widest margins).

4. The best results (i.e., goodness-of-fit tests passed) were observed for the Ohio and Kansas sites for the longest line (316 km) and the largest area (316 km^2).

5. When the goodness-of-fit tests failed, they failed by a large margin, so the determination of the critical values was not a major factor in absolute pass or fail results. In other words, critical values within a few percent window on either side would not have changed our results drastically.

6. The scale distance parameter plays a vital role in the model performance.

7. After subdividing the results by site, season, time, and area or line length, we found that only site and area or line length are significant factors in the results. Thus, the determination of site and the length of the line or size of the area should be carefully considered in the future.

Several possible explanations for these results, and recommendations for improving the results in the future, are discussed below:

1. The scale distance parameter was calculated for only the longest lines (316 km) and largest areas (316 km^2). chosen in our study. The scale distance from the longest lines and largest area were used for the remaining lines and areas. In the future, running the scale distance algorithm for shorter lines and areas should improve the results in those areas.

2. We used the AFGL version of the scale distance algorithm. The BAA algorithm was embedded in this algorithm. In the future, a detailed study of different scale distance algorithms would assure the use of the best method to determine scale distance.

3. There is evidence for mixed distributions in Florida. The model tends to produce U-shaped distributions while

the observed data are somewhat flatter (i.e., more spread over intermediate cloud fractions (5% to 95%)). This is evident in the winter cases over Ohio and Kansas. Meteorologically, stratocumulus cloudiness is persistent over these regions during the winter. This may explain why the observed data are more spread out over intermediate cloud fractions (5% to 95%). If the models were modified to account for winter stratocumulus clouds in these regions, model performance might improve.

4. There is strong evidence for anisotropy in Florida datasets. The models assume isotropic distributions (i.e., evenly distributed cloudiness in all directions), while cloudiness in Florida tends to be aligned in preferred directions (i.e., parallel to the coast) where convection is likely. In the future, if the models accounted for anisotropy in tropical regions, model performance might improve.

5. In certain cases, specifically the shortest lines (10 km) and smallest areas (100 km^2) for the BLA and BAA, and the longest lines for the GIA, the model produced nonmonotonic data (i.e., individual frequencies were negative). This may be a shortcoming in the models, and modifying the models to correct for nonmonotonic data might improve the results.

6. The use of published tables of critical values or simulated (Monte Carlo simulation) critical values would not have changed our results drastically. This is due to the large actual values that we calculated when we performed the statistical tests. In other words, in most cases the tests would have failed no matter what critical values were used.

7. A suggestion for the future is to use other statistical methods such as an RMS fit, to determine if the errors were due to the model itself or some variables such as noise, etc.

8. Our evaluation did not use totally independent data sets (i.e., po and r were derived from the observed data). If totally independent data sets were used, there is a good possibility the results would be worse.

9. The GOES data chosen for this study can have some error especially for the shorter lines and smaller areas, because it is hard to estimate absolute amounts of cloudiness from a GOES satellite at these lines and areas. However, GOES data are the best available for evaluating the models.

In conclusion, one can see from the histograms in Appendix C that the models roughly are similar to the GOES data (at least in shape) especially for the shorter lines and areas. Future improvements to the models to account for model biases, anisotropy, winter stratocumulus, mixed distributions, and nonmonotonic values should improve model performance. In addition, careful calculation of scale distance parameter will also help improve model performance.

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ACKNOWLEDGEMENTS

Work for this study was supported under Contract No. F19628-85-C-0007. Special thanks are extended to Mr. Ernest Talpey and Mr. Daniel Scholten of the TASC for their work in preparing the GOES data. The authors also wish to thank Mr. Ralph Ferraro for his support during the data acquisition phase of the contract. The authors also thank Ms. Penny Angus of AFGL for preparation of the histograms in Appendix I.

Finally, we wish to thank Mrs. Brenda Vallette for typing and editing the final report.

APPENDIX A
IMAGE PROCESSING ALGORITHMS

There are three primary programs which have been written to extract cloud and surface data and process this information into the cloud detection data base. These programs are described below.

A.1 DATSAV TAPE READING PROGRAM

The user must first run the DATSAV tape reading program (Figure A.1) which will extract data from tape files to files which can then be used by the automatic cloud detection program. A brief description follows:

1) User runs the DATSAV tape read program to extract data from the DATSAV tapes for the particular station, year, month, and hours.

2) The program produces a file consisting of surface data for a particular station, year, month, and two hours per day.

A.2 THE MASTER PROGRAM

A cloud detection algorithm has been formulated and is in the final stages of testing. The program uses the GOES images over FL, OH, and KS and the corresponding DATSAV data files for surface observations (ground truth). The following summarizes the steps taken by the MASTER program. (See Figure A.2.)

1) Read the images off the GOES tapes for the appropriate 316 km x 316 km subscene (corresponding to a 100,000 square kilometer area) centered on each of the three ground stations of interest.

2) Register the IR and VIS scenes to one another.

3) Compute a minimum background intensity level map based on five days of images and used for each of those five days (VIS and IR).

4) Locate the mode (peak value) in the background map, and set the entire background map equal to this constant value (VIS and IR).

5) Subtract this background from the image for the day of interest (VIS and IR).

6) Threshold the image (VIS and IR) result at a low residual level (10 to 15) to correct for noise in the image, depending on the station.

7) Compute the cloud cover over 50 km x 50 km regions centered on the ground station for each scene (VIS and IR).

8) Reject the image if the IR cloud determination is greater than three deciles (30%) above the VIS cloud determination.

9) Reject the image if the DATSAV (ground truth) sky cover value differs by more than twenty-five percent from the VIS cloud determination.

10) If not rejected, compute cloud cover over all reference lines and areas, and maximum clear and cloudy runs over all reference lines. Write image file name and image descriptive data to the "GOOD" image data file and update the "CUMULATIVE" data file with the various bin counts.

11) If rejected, write the image file name and associated image descriptive data to the "BAD" image data file.

A.3 THE MASTERI PROGRAM

The third and final program, MASTERI, (Figure A.3) interactively selects the bad images which the user wishes to display, examine, and interactively edit for possible inclusion in the valid image data base. The bad images are listed within the "BAD" image file. This process consists of the following steps:

1) Displaying a selected image on the screen.

2) Interactively threshold the visible image through inspection of the displayed image.

3) Give the interactive program the selected threshold value for computation of new cloud cover statistics.

4) The program updates the "GOOD" and "CUMULATIVE" data files.

5) User can select another image to view if desired.

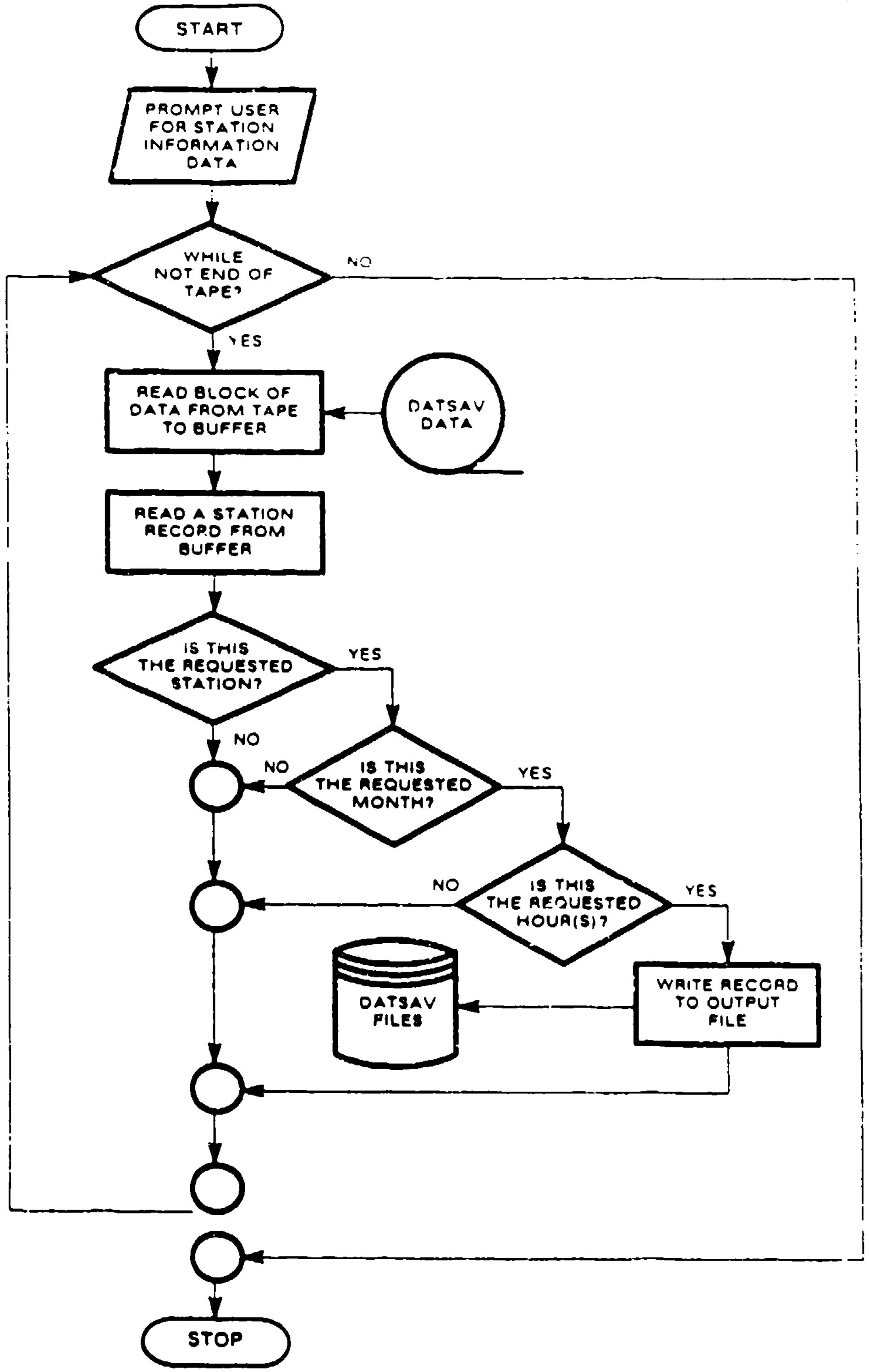

Figure A.1 DATSAV Tape Reading Program Flow Diagram

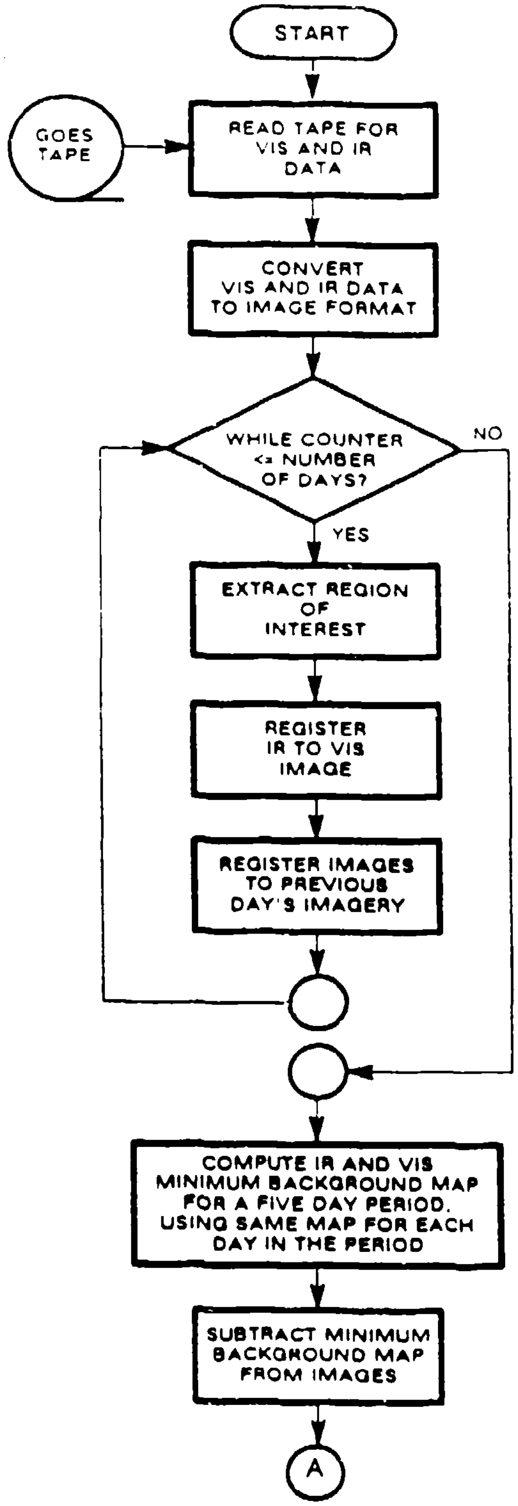

Figure A.2 MASTER Program Flow Diagram

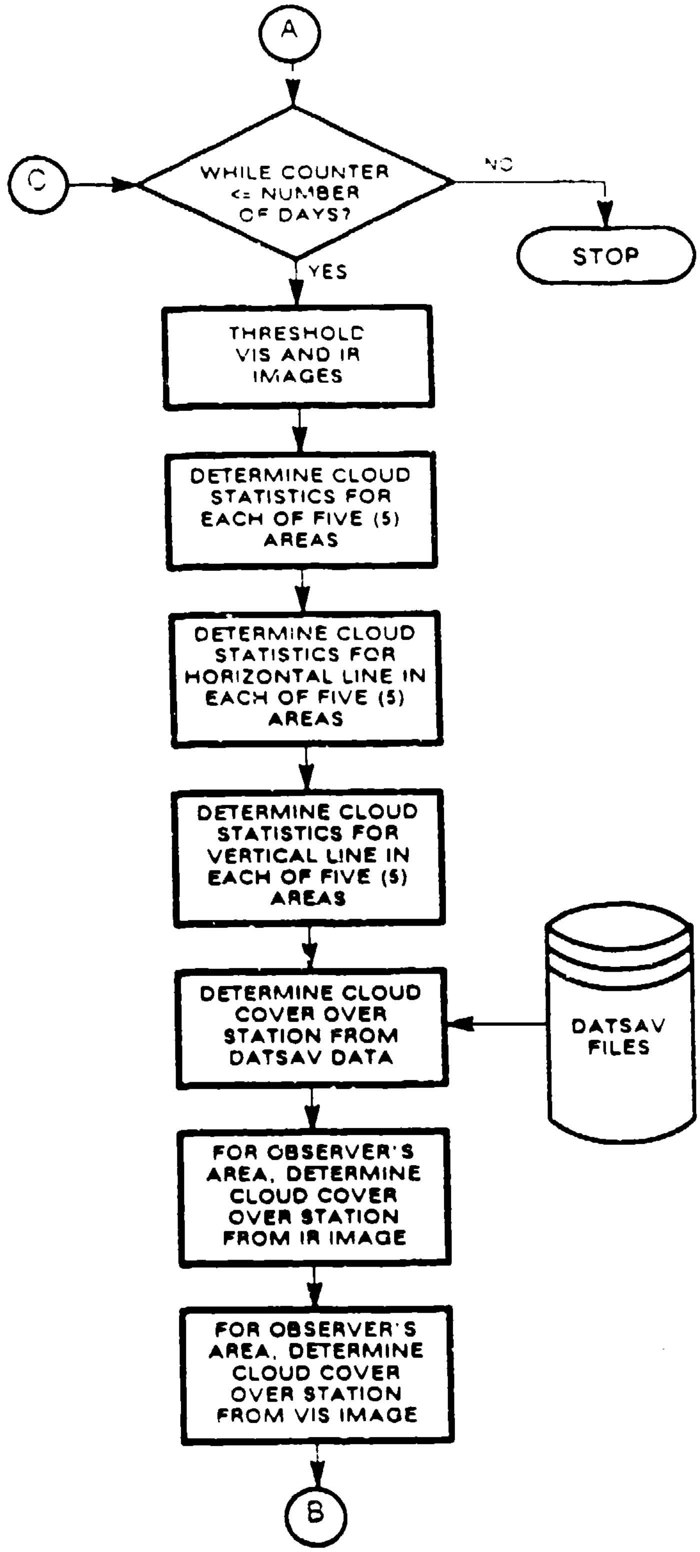

Figure A.2 MASTER Program Flow Diagram (Cont'd)

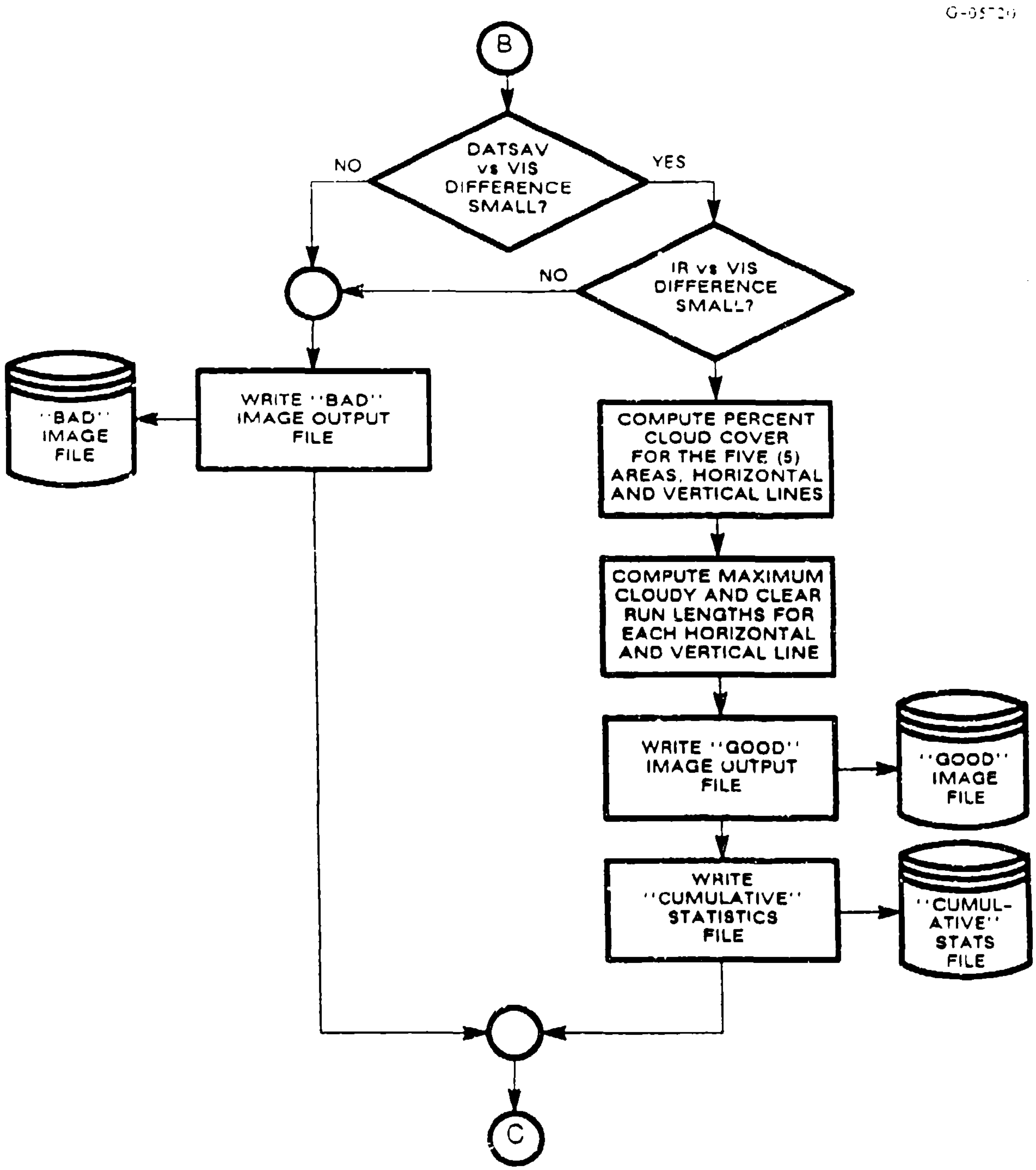

Figure A.2 MASTER Program Flow Diagram (Cont'd)

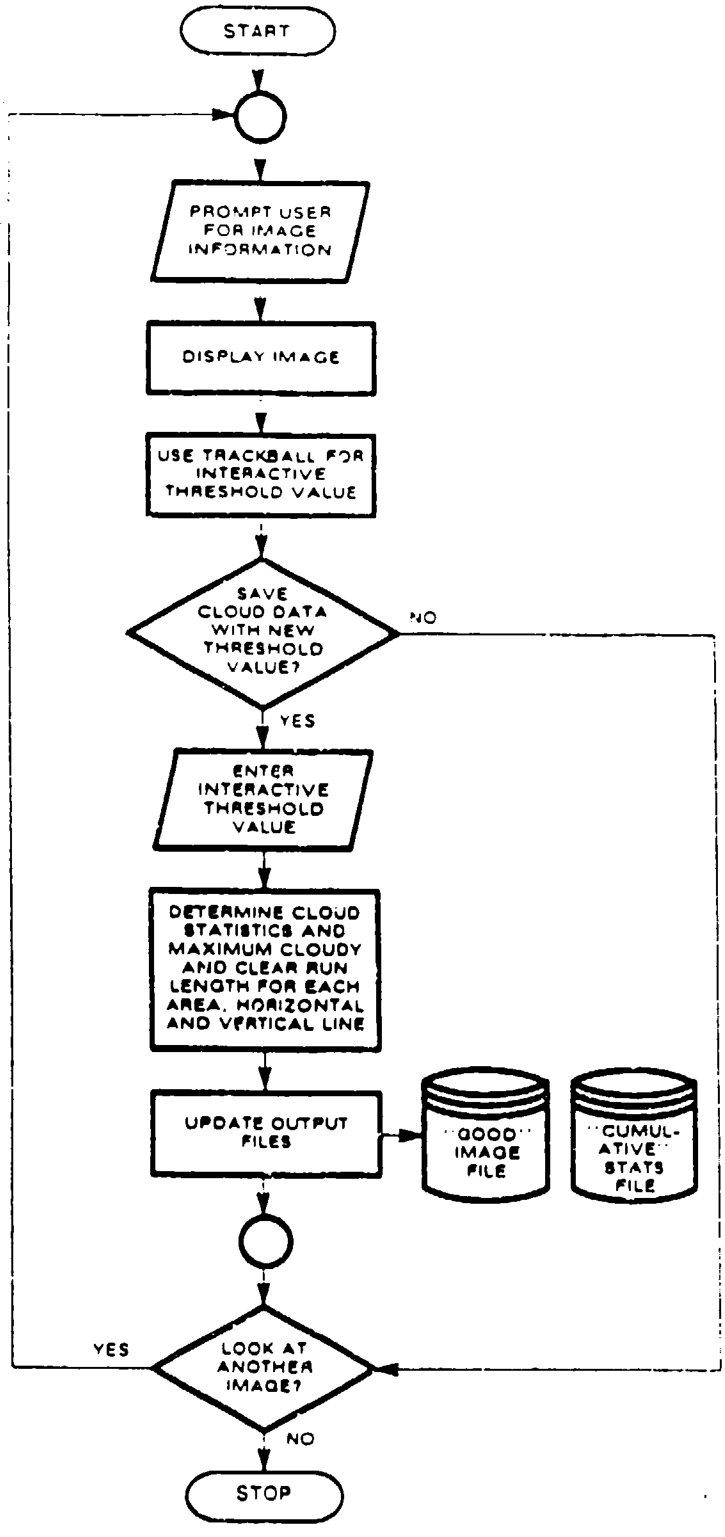

Figure A.3 MASTER1 Program Flow Diagram

APPENDIX B

OUTPUT FILES

CONTENTS OF OUTPUT STATISTICS FILE

Description	Data Type	Range
Image Name (hour, month, day, VIS or IR scene)	Char. String	-
Cloud cover over station, computed (decile)	Integer (nnn)	0-10
Cloud cover over station, computed (fraction)	Float (n.nnnn)	0.0-1.0
Cloud cover over station, ground truth from DATSAV data (Synoptic or Airways)	Integer (nnn)	0-8 or -2,-7,-8,-9
Cloud cover over station, computed from IR Image (decile)	Integer (nnn)	0-10
Background level-visible threshold	Integer (nnnn)	0-255
For each of 5 areas*: cloud cover over area, computed (fraction)	Float (n.nnnnn)	0.0-1.0
For each of 5 Horizontal lines+: cloud cover along line, computed (fraction)	Float (n.nnnnn)	0.0-316.0
Maximum clear run length (km)	Float (nnn.nnnnnn)	0.0-316.0
Maximum cloudy run length (km)	Float (nnn.nnnnn)	0.0-316.0
For each of 5 Vertical lines:++ (same as for Horizontal lines)		

*Areas have sides of 10, 32, 50, 100, and 316 km.
+Lines have the same length as the areas.
++Lines have the same height as the areas.

Note: There will be a separate output statistics file for each of 3 scenes, 2 times of day, 2 seasons, 5 years = 60 files.

Each file has a record for each day for 1 season (3 months).

CONTENTS OF OUTPUT CUMULATIVE STATISTICS FILE

Description	Data Type	Range
For each of 5 Areas:		
For each of 22 Bins:		
Number of days with cloud cover in this bin	Integer (nnnnnn)	0-999999
For each of 5 Horizontal Lines:		
For each of 22 Bins:		
Number of days with cloud cover in this bin	Integer (nnnnnn)	0-999999
For each of 317 Bins:		
Number of days with maximum length clear run in this bin (KM)	Integer (nnnnnn)	0-999999
Number of days with maximum length cloudy run in this bin (KM)	Integer (nnnnnn)	0-999999
For each of 5 Vertical Lines: (same as horizontal lines)		

APPENDIX C

BENCHMARK TESTS FOR BAA, BLA, AND GIA ALGORITHMS

The BLA, BAA, and GIA models were received on floppy disk. We transferred the models to the hard disk on a Leading Edge Computer using MS-DOS. The versions of the BLA and BAA used were those implemented by TASC for the sample size study and were adopted from the AFGL TR 84-0126 written by Burger and Gringorten. The BLA and BAA models were benchmarked against the values printed in the AFGL TR 84-0126. Specifically the BLA and BAA were tested using the mean and scale distance that AFGL derived for cloudiness at Bedford, Mass. for January (1200 - 1400 Lst.). The results are summarized in Tables 1 and 2.

Table 1
BLA Benchmarks for Bedford, MA

May 18, 1988

Cumulative Frequencies

Fraction of Line	10 km		100 km		500 km	
with Cloud	AFGL	RDS	AFGL	RDS	AFGL	RDS
0	0.309	0.308	0.150	0.149	0.004	0.004
0.1	0.314	0.314	0.183	0.182	0.019	0.019
0.2	0.321	0.320	0.228	0.219	0.048	0.048
0.3	0.326	0.326	0.254	0.254	0.100	0.099
0.4	0.333	0.333	0.293	0.292	0.175	0.173
0.5	0.340	0.339	0.332	0.331	0.269	0.268
0.6	0.347	0.346	0.372	0.372	0.387	0.386
0.7	0.353	0.352	0.418	0.417	0.522	0.521
0.8	0.359	0.358	0.462	0.461	0.666	0.665
0.9	0.366	0.365	0.511	0.511	0.803	0.802
1.0	0.371	0.370	0.561	0.561	0.921	0.921
Complete Cover	0.629	0.630	0.439	0.439	0.079	0.079

Table 2
BAA Benchmarks for Bedford, MA

Sky Cover (Tenths)	100 km² AFGL	100 km² RDS	2424 km² AFGL	2424 km² RDS	100,000 km² AFGL	100,000 km² RDS
0	0.250	0.250	0.135	0.135	0.001	0.0002
0.05	0.298	0.297	0.170	0.169	0.001	0.0004
0.15	0.312	0.311	0.220	0.219	0.015	0.0097
0.25	0.321	0.320	0.255	0.254	0.051	0.0352
0.35	0.330	0.323	0.286	0.285	0.121	0.0889
0.45	0.336	0.336	0.316	0.315	0.215	0.1712
0.55	0.344	0.343	0.348	0.347	0.313	0.2949
0.65	0.350	0.349	0.380	0.393	0.459	0.4497
0.75	0.359	0.359	0.417	0.416	0.640	0.6238
0.85	0.369	0.368	0.461	0.460	0.815	0.8016
0.95	0.384	0.383	0.534	0.533	0.978	0.9705
1.00	0.390	0.389	0.610	0.600	0.989	0.9888
Complete Cover	0.610	0.611	0.390	0.400	0.011	0.0112

The BLA is accurate to 0.001 (or 0.1%) for all line lengths (10, 100, 500 km^2). This benchmark procedure provides an independent test that verifies our versions of the BLA, BAA, and GIA algorithms. The BLA is also accurate to 0.001 for areas less than 2424 km^2. However, for the largest areas tested (i.e., 316 km^2), discrepancies did exist. AFGL was alerted to this problem, and expressed no concern. It now appears that the AFGL values for 100,000 km^2 are questionable.

The GIA Algorithm was also benchmarked against results obtained independently from Irv Gringorten (AFGL) from running the Basic version of the GIA at AFGL. We ran the MS-Fortran version of the GIA and produced the same results. A summary of the benchmark is shown in Table 3.

Table 3
GIA Benchmarks

Given: Probability of cloud cover (POP) = .67233
Scale distance (r) = 11.439 km
Total line of travel (T) = 10 km
Intervals from 1 - 10 km within T

RDS (MS-Fortran)		AFGL Basic	
Interval (km)	Probability	Interval (km)	Probability
1	0.35831	1	0.3583091
2	0.34165	2	0.3416529
3	0.33704	3	0.3370353
4	0.33628	4	0.3362764
5	0.33569	5	0.3356880
6	0.33441	6	0.3344093
7	0.33234	7	0.3323397
8	0.33026	8	0.3302611
9	0.32821	9	0.3282092
10	0.32620	10	0.3262018

APPENDIX D

STATISTICAL GOODNESS-OF-FIT RESULTS

This appendix contains a complete list of the results from the goodness-of-fit statistics we performed for the model CDF's versus the satellite CDF's. A total of 7 tables are presented. The breakdown is as follows: 3 tables for BLA results (K-S tests, G-tests, Chi-squared tests); 3 tables for BAA results (K-S tests, g-tests, Chi-squared tests); and 1 table (cloudy and clear runs, K-S tests) for the GIA results. For the BLA and BAA programs, each table contains the critical values for each test (determined in the simulation study) and the actual values from the comparisons for all 12 files and all lines and areas.

The tables clearly show that many of the actual values were quite large, especially for the shorter lines and smaller areas. The tables illustrate that a change in the critical values by a few percent would not have significantly effected the results.

Table D-1: BLA KS-Test Results:

GOES Files	Horz Line	Critical Values	Actual Values	Pass/ Fail	Vertical Line	Critical Values	Actual Values	Pass/ Fail
15 Ohio wi	10	.062	.1050	F	10	.062	.0930	F
	32	.066	.1120	F	32	.066	.1103	F
	50	.067	.0908	F	50	.067	.1368	F
	100	.069	.1187	F	100	.069	.1387	F
	316	.071	.0905	F	316	.071	.0839	F
15 Ohio su	10	.055	.0881	F	10	.055	.1114	F
	32	.059	.0888	F	32	.059	.1053	F
	50	.057	.0859	F	50	.057	.1307	F
	100	.062	.0813	F	100	.062	.1027	F
	316	.066	.0443	P	316	.066	.1047	F
18 Ohio wi	10	.053	.1093	F	10	.053	.1230	F
	32	.058	.1177	F	32	.058	.1209	F
	50	.061	.1178	F	50	.061	.1272	F
	100	.060	.1053	F	100	.060	.1210	F
	316	.063	.0759	M	316	.063	.0978	F
18 Ohio su	10	.051	.1846	F	10	.051	.2014	F
	32	.055	.1882	F	32	.055	.2032	F
	50	.058	.1733	F	50	.058	.2008	F
	100	.060	.1366	F	100	.060	.1916	F
	316	.062	.0957	F	316	.062	.1382	F
15 Kansas wi	10	.063	.0746	F	10	.063	.0887	F
	32	.067	.1018	F	32	.067	.1031	F
	50	.069	.1087	F	50	.069	.1187	F
	100	.067	.0913	F	100	.067	.1147	F
	316	.071	.0576	P	316	.071	.0963	F
15 Kansas su	10	.054	.0825	F	10	.054	.1104	F
	32	.056	.1070	F	32	.056	.1204	F
	50	.058	.1302	F	50	.058	.1328	F
	100	.061	.0996	F	100	.061	.1023	F
	316	.062	.0708	M	316	.062	.0708	F
18 Kansas wi	10	.060	.0933	F	10	.060	.0776	F
	32	.067	.1158	F	32	.067	.0912	F
	50	.069	.1251	F	50	.069	.0954	F
	100	.069	.1431	F	100	.069	.1077	F
	316	.073	.0721	P	316	.073	.0566	P

Table D-1 (continued)

GOES Files	Horz Line	Critical Values	Actual Values	Pass/ Fail	Vertical Line	Critical Values	Actual Values	Pass/ Fail
18 Kansas su	10	.054	.0933	F	10	.054	.1005	F
	32	.056	.1158	F	32	.056	.1055	F
	50	.058	.1251	F	50	.058	.1303	F
	100	.061	.1431	F	100	.061	.1164	F
	316	.062	.0797	M	316	.062	.0926	F
15 Florida wi	10	.055	.1000	F	10	.055	.1239	F
	32	.060	.1463	F	32	.060	.1661	F
	50	.061	.1782	F	50	.061	.1858	F
	100	.063	.2276	F	100	.063	.1928	F
	316	.064	.2000	F	316	.064	.1477	F
15 Florida su	10	.051	.1575	F	10	.051	.1894	F
	32	.056	.2245	F	32	.056	.2493	F
	50	.057	.2422	F	50	.057	.2917	F
	100	.061	.2626	F	100	.061	.2849	F
	316	.061	.1773	F	316	.061	.1623	F
18 Florida wi	10	.055	.1170	F	10	.055	.1353	F
	32	.058	.1722	F	32	.058	.1414	F
	50	.058	.1905	F	50	.058	.1516	F
	100	.060	.2293	F	100	.060	.1649	F
	316	.062	.1966	F	316	.062	.1695	F
18 Florida su	10	.055	.1897	F	10	.055	.2159	F
	32	.061	.2639	F	32	.061	.2664	F
	50	.060	.2955	F	50	.060	.2738	F
	100	.062	.3181	F	100	.062	.2699	F
	316	.062	.2247	F	316	.062	.1248	F

Table D-2: BLA G-Test Results:

GOES File	Horz. Line(km)	No. Comb. Bins	Critical Values	Actual Values	Pass/ Fail	Vert. Line(km)	Critical Values	Actual Values	Pass/ Fail
15 Ohio wi	10	3	5.53	221.77	F	10	5.53	198.93	F
	32	6	10.11	117.38	F	32	10.11	106.38	F
	50	7	14.64	64.38	F	50	14.64	94.88	F
	100	11	17.96	84.88	F	100	17.96	107.85	F
	316	20	29.74	40.82	F	316	29.74	36.38	F
15 Ohio su	10	3	5.91	170.99	F	10	5.91	208.49	F
	32	6	12.05	80.35	F	32	12.05	86.13	F
	50	8	14.98	86.42	F	50	14.98	172.64	F
	100	11	19.16	76.30	F	100	19.16	95.67	F
	316	20	32.28	38.94	F	316	32.28	59.91	F
18 Ohio wi	10	2	4.82	20.69	F	10	4.82	26.07	F
	32	5	9.13	82.54	F	32	9.13	95.65	F
	50	6	13.51	77.16	F	50	13.51	114.22	F
	100	11	17.45	82.54	F	100	17.45	131.22	F
	316	19	28.92	38.82	F	316	28.92	54.64	F
18 Ohio su	10	4	8.43	473.48	F	10	8.43	471.14	F
	32	9	14.65	317.68	F	32	14.65	324.04	F
	50	11	18.98	272.59	F	50	18.98	371.09	F
	100	20	28.75	161.94	F	100	28.75	265.08	F
	316	20	31.32	55.61	F	316	31.32	100.33	F
15 Kansas wi	10	2	4.10	5.71	M	10	4.10	7.49	F
	32	5	9.08	93.26	F	32	9.08	108.05	F
	50	6	11.66	97.26	F	50	11.66	122.62	F
	100	11	18.12	74.19	F	100	18.12	91.97	F
	316	20	29.57	33.86	F	316	29.57	42.68	F
15 Kansas su	10	3	5.56	150.66	F	10	5.56	217.48	F
	32	6	10.95	97.20	F	32	10.95	135.79	F
	50	8	13.96	147.50	F	50	13.96	148.27	F
	100	11	19.29	78.56	F	100	19.29	87.61	F
	316	20	33.36	40.64	F	316	33.36	51.64	F
18 Kansas wi	10	2	4.42	5.42	M	10	4.42	7.18	F
	32	5	10.39	51.00	F	32	10.39	69.77	F
	50	6	13.34	64.44	F	50	13.34	64.80	F
	100	11	19.03	23.53	F	100	19.03	77.64	F
	316	20	30.67	19.39	P	316	30.67	34.64	M
18 Kansas su	10	3	5.69	226.27	F	10	5.69	180.00	F
	32	7	13.77	145.01	F	32	13.77	121.46	F
	50	8	16.51	175.94	F	50	16.51	184.17	F
	100	11	21.50	127.67	F	100	21.50	115.56	F
	316	20	30.79	67.24	F	316	30.79	61.00	F

BLA G-Test Results: (Table D-2 Continued)

GOES File	Horz. Line(km)	No. Comb. Bins	Critical Values	Actual Values	Pass/ Fail	Vert. Line(km)	Critical Values	Actual Values	Pass/ Fail
15 Florida wi	10	3	6.15	133.91	F	10	6.15	155.97	F
	32	8	13.53	229.39	F	32	13.53	249.88	F
	50	9	15.64	233.07	F	50	15.64	222.58	F
	100	11	22.08	266.70	F	100	22.08	247.82	F
	316	20	29.76	192.54	F	316	29.76	150.37	F
15 Florida su	10	5	9.94	329.90	F	10	9.94	372.87	F
	32	11	19.36	338.55	F	32	19.36	418.79	F
	50	11	23.15	320.36	F	50	23.15	476.01	F
	100	20	29.63	311.55	F	100	29.63	386.72	F
	316	20	30.14	174.44	F	316	30.14	200.94	F
18 Florida wi	10	3	6.55	181.91	F	10	6.55	194.98	F
	32	8	13.79	222.88	F	32	13.79	208.69	F
	50	10	15.48	230.42	F	50	15.48	204.86	F
	100	11	22.21	243.66	F	100	22.21	194.66	F
	316	20	30.11	190.26	F	316	30.11	149.82	F
18 Florida su	10	5	10.54	313.31	F	10	10.54	374.78	F
	32	11	17.83	369.11	F	32	17.83	408.70	F
	50	11	22.97	386.32	F	50	22.97	389.76	F
	100	20	32.31	364.01	F	100	32.31	377.25	F
	316	20	30.09	247.51	F	316	30.09	158.49	F

Table D-3: BLA CHI-SQUARED RESULTS

GOES Files	Horz Line(km)	No. Comp. Bins	Critical Values	Actual Values	Pass/ Fail	Vertical Line(km)	Critical Values	Actual Values	Pass/ Fail
15 Ohio wi	10	3	5.600	693.58	F	10	5.600	601.93	F
	32	6	10.234	192.38	F	32	10.234	174.91	F
	50	7	14.954	87.66	F	50	14.954	140.47	F
	100	11	18.225	134.12	F	100	18.225	160.85	F
	316	20	28.195	49.48	F	316	28.195	40.11	F
15 Ohio su	10	3	5.759	492.32	F	10	5.759	638.56	F
	32	6	13.561	122.09	F	32	13.561	159.06	F
	50	8	15.201	127.88	F	50	15.201	297.94	F
	100	11	19.210	110.66	F	100	19.210	131.81	F
	316	20	31.605	44.68	F	316	31.605	66.11	F
18 Ohio wi	10	2	4.620	18.80	F	10	4.620	23.35	F
	32	5	8.766	125.14	F	32	8.766	154.36	F
	50	6	13.600	102.47	F	50	13.600	172.22	F
	100	11	18.735	111.39	F	100	18.735	179.48	F
	316	19	30.100	43.73	F	316	30.100	63.08	F
18 Ohio su	10	4	9.741	1407.21	F	10	9.741	1346.93	F
	32	9	15.325	577.59	F	32	15.325	517.18	F
	50	11	18.728	385.65	F	50	18.728	570.42	F
	100	20	29.766	202.59	F	100	29.766	337.15	F
	316	20	31.341	56.02	F	316	31.341	90.38	F
15 Kansas wi	10	2	4.129	5.19	M	10	4.129	7.52	F
	32	5	10.406	169.24	F	32	10.406	192.09	F
	50	6	11.028	177.54	F	50	11.028	217.39	F
	100	11	18.236	108.83	F	100	18.236	135.18	F
	316	20	29.610	38.43	F	316	29.610	46.51	F
15 Kansas su	10	3	4.852	418.65	F	10	4.852	684.27	F
	32	6	10.834	154.29	F	32	10.406	192.09	F
	50	8	14.107	231.63	F	50	14.107	229.71	F
	100	11	18.208	101.31	F	100	18.208	116.24	F
	316	20	31.362	47.66	F	316	31.362	61.26	F
18 Kansas wi	10	2	3.611	5.37	F	10	3.611	7.10	F
	32	5	9.800	86.52	F	32	9.800	113.52	F
	50	6	12.353	105.25	F	50	12.353	96.56	F
	100	11	18.816	29.11	F	100	18.816	105.32	F
	316	20	31.329	22.17	P	316	31.329	34.48	M

BLA CHI-SQUARED RESULTS: (Table D-3 Continued)

GOES Files	Horz Line(km)	No. Comp. Bins	Critical Values	Actual Values	Pass/ Fail	Vertical Line(km)	Critical Values	Actual Values	Pass/ Fail
18 Kansas su	10	3	5.37	736.27	F	10	5.37	535.83	F
	32	7	13.12	259.43	F	32	13.12	198.28	F
	50	8	16.39	296.43	F	50	16.39	305.87	F
	100	11	21.11	173.28	F	100	21.11	154.90	F
	316	20	30.80	81.08	F	316	30.80	79.51	F
15 Florida wi	10	3	6.41	346.77	F	10	6.41	416.51	F
	32	8	15.15	408.23	F	32	15.15	435.15	F
	50	9	16.97	391.96	F	50	16.97	358.56	F
	100	11	21.77	349.42	F	100	21.77	335.03	F
	316	20	30.03	167.19	F	316	30.03	158.22	F
15 Florida su	10	5	9.28	864.90	F	10	9.28	1008.10	F
	32	11	17.37	595.27	F	32	17.37	812.51	F
	50	11	23.36	477.82	F	50	23.36	821.08	F
	100	20	30.39	404.11	F	100	30.39	557.64	F
	316	20	29.73	162.79	F	316	29.73	197.70	F
18 Florida wi	10	3	6.14	518.75	F	10	6.14	561.07	F
	32	8	14.39	389.82	F	32	14.39	376.09	F
	50	10	16.11	348.10	F	50	16.11	317.40	F
	100	11	22.20	303.78	F	100	22.20	260.09	F
	316	20	30.98	159.51	F	316	30.98	161.82	F
18 Florida su	10	5	9.99	782.74	F	10	9.99	968.38	F
	32	11	18.69	632.04	F	32	18.69	735.79	F
	50	11	22.44	564.13	F	50	22.44	595.47	F
	100	20	32.21	397.55	F	100	32.31	502.86	F
	316	20	30.09	178.40	F	316	30.09	174.32	F

Table D-4: BAA K-S Test Results

GOES File	SQ.km Area	Critical Values	Actual Values	Pass/ Marginal/ Fail
15Z Ohio Winter	100	.065	.1377	F
	1024	.068	.1546	F
	2500	.068	.1565	F
	10000	.068	.1970	F
	100000	.071	.1180	F
15Z Ohio Summer	100	.055	.1319	F
	1024	.058	.1241	F
	2500	.060	.1079	F
	10000	.063	.0861	M
	100000	.068	.0271	P
18Z Ohio Winter	100	.055	.2235	F
	1024	.060	.2031	F
	2500	.060	.1720	F
	10000	.063	.1396	F
	100000	.065	.0336	P
18Z Ohio Summer	100	.051	.112[illegible]	F
	1024	.056	.1247	F
	2500	.058	.1268	F
	10000	.062	.0870	M
	100000	.059	.0341	P
15Z Kansas Winter	100	.063	.1129	F
	1024	.069	.1247	F
	2500	.068	.1268	F
	10000	.070	.0870	M
	100000	.072	.0341	P
15Z Kansas Summer	100	.056	.1201	F
	1024	.058	.1345	F
	2500	.062	.1260	F
	10000	.061	.0885	F
	100000	.062	.0361	P
18Z Kansas Winter	100	.063	.0853	F
	1024	.069	.1031	F
	2500	.069	.0900	F
	10000	.071	.0735	M
	100000	.074	.0398	P
18Z Kansas Summer	100	.057	.1[illegible]45	F
	1024	.061	.1349	F
	2500	.062	.1249	F
	10000	.065	.1013	F
	100000	.065	.0252	P

Table D-4: BAA K-S Test Results

GOES File	SQ.km Area	Critical Values	Actual Values	Pass/ Marginal/ Fail
15Z Florida Winter	100	.056	.1535	F
	1024	.062	.1769	F
	2500	.063	.1891	F
	10000	.064	.1660	F
	100000	.064	.1212	F
15Z Florida Summer	100	.053	.2303	F
	1024	.056	.2895	F
	2500	.059	.2995	F
	10000	.061	.2480	F
	100000	.061	.0904	F
18Z Florida Winter	100	.055	.1403	F
	1024	.059	.1795	F
	2500	.060	.1728	F
	10000	.063	.1643	F
	100000	.061	.1145	F
18Z Florida Summer	100	.056	.2729	F
	1024	.061	.3086	F
	2500	.062	.3019	F
	10000	.062	.2256	F
	100000	.062	.0936	F

Table D-5: BAA G-Test Results

GOES File	SQ.km Area	Critical Values	Actual Values	Pass/ Marginal/ Fail
15Z Ohio Winter	100	6.815	28.63	F
	1024	13.332	164.79	F
	2500	16.204	220.22	F
	10000	22.220	197.33	F
	100000	30.271	74.33	F
15Z Ohio Summer	100	6.753	232.92	F
	1024	16.246	133.84	F
	2500	18.031	98.03	F
	10000	26.966	46.58	F
	100000	30.555	20.08	P
18Z Ohio Winter	100	6.093	154.79	F
	1024	13.088	156.18	F
	2500	15.823	126.99	F
	10000	22.307	68.60	F
	100000	30.118	28.86	P
18Z Ohio Summer	100	9.886	619.96	F
	1024	17.964	366.11	F
	2500	23.966	264.00	F
	10000	30.649	147.91	F
	100000	30.118	24.92	P
15Z Kansas Winter	100	5.987	193.33	F
	1024	12.197	137.85	F
	2500	15.649	109.55	F
	10000	19.895	48.86	F
	100000	30.329	18.07	P
15Z Kansas Summer	100	6.445	142.23	F
	1024	15.320	166.91	F
	2500	17.345	119.60	F
	10000	26.959	54.35	F
	100000	28.863	34.11	M
18Z Kansas Winter	100	6.287	75.92	F
	1024	13.547	80.62	F
	2500	16.453	63.27	F
	10000	20.175	30.60	F
	100000	32.460	24.77	P
18Z Kansas Summer	100	8.626	256.41	F
	1024	16.150	170.37	F
	2500	18.377	133.20	F
	10000	28.139	78.82	F
	100000	30.055	17.73	P

Table D-5: BAA G-Test Results (Continued)

GOES File	SQ.km Area	Critical Values	Actual Values	Pass/ Marginal/ Fail
15Z Florida Winter	100	7.958	254.16	F
	1024	17.813	254.11	F
	2500	20.658	251.85	F
	10000	28.333	187.73	F
	100000	31.115	96.92	F
15Z Florida Summer	100	12.049	451.53	F
	1024	22.838	421.21	F
	2500	28.686	386.75	F
	10000	28.908	270.63	F
	100000	27.317	166.18	F
18Z Florida Winter	100	8.124	246.53	F
	1024	15.657	236.26	F
	2500	21.559	193.21	F
	10000	29.508	148.70	F
	100000	29.137	110.06	F
18Z Florida Summer	100	12.928	515.04	F
	1024	23.783	442.16	F
	2500	31.354	375.27	F
	10000	29.171	234.64	F
	100000	28.898	130.13	F

Table D-6: BAA CHI.SQ. Test Results

GOES File	SQ.Km Area	Critical Values	Actual Values	Pass/ Marginal/ Fail
15Z Ohio Winter	100	7.046	25.63	F
	1024	13.226	316.86	F
	2500	16.347	399.78	F
	10000	23.207	312.43	F
	100000	31.032	89.24	F
15Z Ohio Summer	100	7.150	573.23	F
	1024	16.801	208.93	F
	2500	18.753	138.16	F
	10000	26.474	51.81	F
	100000	31.572	19.47	P
18Z Ohio Winter	100	5.974	366.86	F
	1024	13.220	249.21	F
	2500	15.842	171.02	F
	10000	22.373	81.10	F
	100000	30.846	29.12	P
18Z Ohio Summer	100	9.556	1692.07	F
	1024	18.196	553.09	F
	2500	23.846	366.12	F
	10000	30.596	168.71	F
	100000	30.376	24.81	P
15Z Kansas Winter	100	6.026	578.36	F
	1024	10.971	228.64	F
	2500	15.419	165.60	F
	10000	20.146	59.95	F
	100000	29.758	18.08	P
15Z Kansas Summer	100	6.913	377.49	F
	1024	14.799	278.89	F
	2500	16.976	169.83	F
	10000	27.791	66.76	F
	100000	29.201	34.48	M
18Z Kansas Winter	100	5.352	167.08	F
	1024	13.560	117.94	F
	2500	16.949	94.24	F
	10000	19.872	36.24	F
	100000	32.275	23.52	P
18Z Kansas Summer	100	9.642	688.99	F
	1024	17.275	245.66	F
	2500	18.705	175.84	F
	10000	29.224	92.72	F
	100000	30.564	17.98	P

Table D-6: BAA CHI.SQ. Test Results (Continued)

GOES File	SQ.km Area	Critical Values	Actual Values	Pass/ Marginal/ Fail
15Z Florida Winter	100	8.496	609.58	F
	1024	18.574	396.12	F
	2500	21.038	344.54	F
	10000	29.985	226.22	F
	100000	31.807	88.07	F
15Z Florida Summer	100	12.427	1125.89	F
	1024	22.895	660.94	F
	2500	28.523	525.27	F
	10000	29.544	298.93	F
	100000	27.366	235.05	F
18Z Florida Winter	100	7.776	589.76	F
	1024	15.415	371.89	F
	2500	20.565	251.45	F
	10000	29.240	169.28	F
	100000	29.633	89.32	F
18Z Florida Summer	100	12.898	1207.03	F
	1024	24.214	681.47	F
	2500	29.629	469.10	F
	10000	30.145	240.90	F
	100000	28.783	154.06	F

Table D-7
GIA Statistics

FILE	CLEAR RUN CHI-SQ	G-TEST	KS	# COMBINED BINS	CLOUDY RUN CHI-SQ	G-TESTS	KS	# COMBINED BINS
15 OHW 10KM	1.727	5.646	.0379	2 pass	172.39	87.08	.1017	2 pass
32KM	198.07	141.02	.1122	4	169.97	129.47	.0830	4
50KM	314.10	183.77	.1282	6	205.26	154.12	.1090	6
100KM	337.00	228.74	.1256	10	127.97	135.46	.1367	10
316KM	291.64	297.27	.1554	20	123.73	123.80	.1039	20
15 OHS 10KM	84.75	56.24	.0573	3	110.02	66.56	.0654	3
32KM	169.56	130.86	.0863	7	134.55	114.13	.0684	7
50KM	201.09	172.09	.0971	10	138.40	133.03	.0901	10
100KM	213.79	213.20	.1024	17	191.57	188.24	.0919	17
316KM	324.63	294.43	.1107	38	290.11	260.62	.0972	38
18 OHW 10KM	0.232	10.26	.0149	2 pass	179.05	91.24	.0963	3
32KM	253.49	147.36	.1081	6	194.49	126.60	.0814	6
50KM	308.18	185.00	.1260	8	213.52	150.03	.0848	8
100KM	278.45	221.36	.1202	13	157.72	151.19	.1089	13
316KM	245.16	309.50	.1667	28	83.03	91.67	.1079	28
18 OHS 10KM	1161.82	333.63	.2053	3	863.40	276.78	.1818	3
32KM	936.60	440.51	.1873	9	921.27	442.70	.1570	8
50KM	773.53	436.06	.1790	13	641.23	337.09	.1740	13
100KM	681.38	462.54	.1572	23	423.29	315.72	.1945	22
316KM	520.33	423.78	.0815	49	416.62	320.98	.1150	49
15 KSW 10KM	87.01	55.57	.0720	3	88.99	56.51	.0722	3
32KM	134.83	101.92	.0735	5	209.79	125.95	.1080	5
50KM	155.01	133.84	.1159	8	155.78	132.00	.1025	8
100KM	118.04	142.18	.1137	13	108.40	140.42	.1021	13
316KM	195.36	202.21	.1006	29	273.54	270.75	.1607	29
15 KSS 10KM	74.83	52.72	.0529	3	36.23	35.07	.0369	3
32KM	214.44	157.55	.0923	7	215.46	148.31	.0716	7
50KM	287.52	200.40	.1202	10	224.69	184.73	.0745	9
100KM	218.70	216.68	.1059	16	169.17	223.92	.1025	16
316KM	245.10	248.70	.1033	37	280.81	326.63	.1344	36
18 KSW 10KM	29.76	29.56	.0421	3	20.09	24.22	.0352	3
32KM	51.11	62.61	.0691	6	85.98	78.03	.0644	6
50KM	56.56	83.57	.0882	8	113.93	107.53	.0686	8
100KM	63.53	119.65	.1346	14	83.34	128.46	.0733	14
316KM	229.35	241.62	.1867	31	209.40	202.81	.1432	31

Table D-7 (continued)
GIA Statistics

FILE	CLEAR RUN CHI-SQ	G-TEST	KS	# COMBINED BINS	CLOUDY RUN CHI-SQ	G-TESTS	KS	# COMBINED BINS
18 KSS 10KM	271.72	123.16	.0997	3	219.99	106.42	.0894	3
32KM	370.18	204.78	.1042	7	336.37	206.20	.1166	7
50KM	475.04	259.58	.1259	10	363.88	225.77	.1359	10
100KM	432.37	304.72	.1389	17	335.95	277.47	.1562	18
316KM	425.15	349.14	.1654	40	685.93	401.95	.1499	40
15 FLW 10KM	154.22	82.02	.0773	3	394.04	155.26	.1242	3
32KM	442.91	259.23	.1280	7	443.31	258.33	.1286	7
50KM	429.65	284.91	.1950	11	542.62	326.43	.1678	11
100KM	426.17	377.43	.2672	19	617.61	416.78	.1478	19
316KM	414.20	468.86	.1862	41	362.35	327.38	.1033	41
15 FLS 10KM	393.73	187.86	.0944	4	648.80	242.02	.1484	4
32KM	517.33	342.23	.2295	12	1441.58	531.41	.2245	12
50KM	429.96	327.14	.2899	16	1084.68	538.06	.2550	16
100KM	395.34	368.36	.3175	28	864.99	552.24	.2579	28
316KM	532.41	495.95	.2033	57	657.03	499.90	.1097	51
18 FLW 10KM	245.75	111.88	.0979	3	364.25	146.54	.1202	3
32KM	359.10	242.19	.1649	7	551.45	292.13	.1245	7
50KM	336.56	272.92	.2093	11	469.22	308.78	.1414	11
100KM	319.98	314.81	.2440	19	465.38	345.72	.1328	19
316KM	397.34	441.20	.1850	41	325.43	318.03	.0789	41
18 FLS 10KM	393.35	186.28	.0946	4	570.53	230.22	.1300	4
32KM	580.12	387.22	.2747	12	1318.89	540.92	.2604	12
50KM	492.76	386.51	.3079	16	864.58	502.35	.2662	16
100KM	462.89	466.16	.3431	29	768.77	570.07	.2770	29
316KM	529.36	559.65	.1791	59	426.11	437.33	.0929	59

Table D-7 (continued)

GIA Statistics

FILE	CLEAR RUN CHI-SQ	G-TEST	KS	# COMBINED BINS	CLOUDY RUN CHI-SQ	G-TESTS	KS	# COMBINED BINS
15 OHW 10KM	1.727	5.646	.0379	2 pass	172.39	87.08	.1017	2 pass
32KM	198.07	141.02	.1122	4	169.97	129.47	.0830	4
50KM	314.10	183.77	.1282	6	205.26	154.12	.1090	6
100KM	337.00	228.74	.1256	10	127.97	135.46	.1367	10
316KM	291.64	297.27	.1554	20	123.73	123.80	.1039	20
15 OHS 10KM	84.75	56.24	.0573	3	110.02	66.56	.0654	3
32KM	169.56	130.86	.0863	7	134.55	114.13	.0684	7
50KM	201.09	172.09	.0971	10	138.40	133.03	.0901	10
100KM	213.79	213.20	.1024	17	191.57	188.24	.0919	17
316KM	324.63	294.43	.1107	38	290.11	260.62	.0972	38
18 OHW 10KM	0.232	10.26	.0149	2 pass	179.05	91.24	.0963	3
32KM	253.49	147.36	.1081	6	194.49	126.60	.0814	6
50KM	308.18	185.00	.1260	8	213.52	150.03	.0848	8
100KM	278.45	221.36	.1202	13	157.72	151.19	.1089	13
316KM	245.16	309.50	.1667	28	83.03	91.67	.1079	28
18 OHS 10KM	1161.82	333.63	.2053	3	863.40	276.78	.1818	3
32KM	936.60	440.51	.1873	9	921.27	442.70	.1570	8
50KM	773.53	436.06	.1790	13	641.23	337.09	.1740	13
100KM	681.38	462.54	.1572	23	423.29	315.72	.1945	22
316KM	520.33	423.78	.0815	49	416.62	320.98	.1150	49
15 KSW 10KM	87.01	55.57	.0720	3	88.99	56.51	.0722	3
32KM	134.83	101.92	.0735	5	209.79	125.95	.1080	5
50KM	155.01	133.84	.1159	8	155.78	132.00	.1025	8
100KM	118.04	142.18	.1137	13	108.40	140.42	.1021	13
316KM	195.36	202.21	.1006	29	273.54	270.75	.1607	29
15 KSS 10KM	74.83	52.72	.0529	3	36.23	35.07	.0369	3
32KM	214.44	157.55	.0923	7	215.46	148.31	.0716	7
50KM	287.52	200.40	.1202	10	224.69	184.73	.0745	9
100KM	218.70	216.68	.1059	16	169.17	223.92	.1025	16
316KM	245.10	248.70	.1033	37	280.81	326.63	.1344	36
18 KSW 10KM	29.76	29.56	.0421	3	20.09	24.22	.0352	3
32KM	51.11	62.61	.0691	6	85.98	78.03	.0644	6
50KM	56.36	83.57	.0882	8	113.93	107.53	.0686	8
100KM	63.53	119.65	.1346	14	83.34	128.46	.0733	14
316KM	229.35	241.62	.1867	31	209.40	202.81	.1432	31

Table D-7 (continued)
GIA Statistics

FILE	CLEAR RUN CHI-SQ	G-TEST	KS	# COMBINED BINS	CLOUDY RUN CHI-SQ	G-TESTS	KS	# COMBINED BINS
18 KSS 10KM	271.72	123.16	.0997	3	219.99	106.42	.0894	3
32KM	370.18	204.78	.1042	7	336.37	206.20	.1166	7
50KM	475.04	259.58	.1259	10	363.88	225.77	.1359	10
100KM	432.37	304.72	.1389	17	335.95	277.47	.1562	18
316KM	425.15	349.14	.1654	40	685.93	401.95	.1499	40
15 FLW 10KM	154.22	82.02	.0773	3	394.04	155.26	.1242	3
32KM	442.91	259.23	.1280	7	443.31	258.33	.1286	7
50KM	429.65	284.91	.1950	11	542.62	326.43	.1678	11
100KM	426.17	377.43	.2672	19	617.61	416.78	.1478	19
316KM	414.20	468.86	.1862	41	362.35	327.38	.1033	41
15 FLS 10KM	393.73	187.86	.0944	4	648.80	242.02	.1484	4
32KM	517.33	342.23	.2295	12	1441.58	531.41	.2245	12
50KM	429.96	327.14	.2899	16	1084.68	538.06	.2550	16
100KM	395.34	368.36	.3175	28	864.99	552.24	.2579	28
316KM	532.41	495.95	.2033	57	657.03	499.90	.1097	51
18 FLW 10KM	245.75	111.88	.0979	3	364.25	146.54	.1202	3
32KM	359.10	242.19	.1649	7	551.45	292.13	.1245	7
50KM	336.56	272.92	.2093	11	469.22	308.78	.1414	11
100KM	319.98	314.81	.2440	19	465.38	345.72	.1328	19
316KM	397.34	441.20	.1850	41	325.43	318.03	.0789	41
18 FLS 10KM	393.35	186.28	.0946	4	570.53	230.22	.1300	4
32KM	580.12	387.22	.2747	12	1318.89	540.92	.2604	12
50KM	492.76	386.51	.3079	16	864.58	502.35	.2662	16
100KM	462.89	466.16	.3431	29	768.77	570.07	.2770	29
316KM	529.36	559.65	.1791	59	426.11	437.33	.0929	59

APPENDIX E

DESCRIPTION OF STATISTICAL GOODNESS-OF-FIT TESTS

The basic methodology for determining model error bounds in this project was the statistical goodness-of-fit between empirical and model-predicted (theoretical) statistical distributions. Three different goodness-of-fit tests, (Sokal and Rohlf, pp. 691-731) were employed. Two of the tests, the Kolmogorov-Smirnov (K-S) test and the G-Tests, each have unique advantages. The third test, the chi-square test, was included because it is the traditional goodness-of-fit test and because including it did not significantly impact project cost.

With continuous data, the K-S Test is the most powerful test of the three considered here. Moreover, as the greatest absolute difference between empirical and model predicted cumulative relative frequency distributions, and K-S test statistic is a parameter of direct interest. The K-S statistic is defined as:

$$\text{K-S} = \text{Max}|PM_i - PO_i|;\ i=1,\ 20$$

where: PM_i = model cumulative probability for iTH interval

PO_i = observed cumulative probability for iTH interval

Unfortunately, the standard K-S test cannot be used to evaluate the AFGL models because three of its assumptions were violated:

- satellite observations of sky cover were discrete rather than continuous

- model parameters were estimated from the data (intrinsic null hypothesis) rather than being known a priori.

- sky cover data from sequential days is serially correlated (linearly dependent) rather than independent.

The continuity assumption was most nearly correct for large areas with many potential values of sky cover (many pixels per scene). It was least valid for short lines with few potential values for sky cover. Violation of the continuity assumption makes the standard K-S test more conservative (Sokal and Rohlf, p. 720). That is, the standard test will reject a false null hypothesis of equality of distributions less often than expected under the stated significance level. Several modifications of the standard K-S test to account for discrete data have been used (Gleser; Pettit and Stephens).

The assumption of an extrinsic null hypothesis is invalid. Two model parameters (scale distance and mean sky cover) were estimated from the data for one size line or area and applied with all sizes of lines and areas. Violation of the extrinsic assumption makes the standard K-S test more conservative.

The degree of serial correlation in sky cover data will vary with location, time of day, and season. On average, however, the 24 hr serial correlation of sky cover is slightly greater than 0.2 (McCabe, p. 8). In general, violation of the assumption of independence reduces the effective sample size and makes the standard K-S test less conservative.

None of the available K-S tests, standard or modified, can account for all of the violations of assumptions which occur when determining error bounds for the AFGL models. Thus, we were not able to employ published tables of critical values. Consequently, in order to use a K-S type of test, it was necessary to estimate test statistic critical values through Monte Carlo simulation of the entire validation process.

The G test statistic for the goodness-of-fit is based on information theory. It is defined to be twice the amount of information in the sample which is available for discriminating between the expected distribution and the observed distribution:

$$G = 2\,[O_1 \ln (O_1/E_1) + \ldots + O_k/E_k)] \qquad (3.5\text{-}1)$$

where k is the number of cells, O_i is the observed frequency in cell i, and E_i is the expected (model predicted) frequency in cell

i. Test statistic G is approximately distributed as a chi-square variate with k-1-p degrees of freedom where p is the number of distribution parameters which are estimated from the sample of data. Common practice dictates that if $E_i < 5$, then cell i is combined with a neighboring cell. Also, for a closer approximation to the chi-square distribution, G is commonly adjusted as follows:

$$G_{adj} = G/\{1 + (k^2-1)/[6N(k-p-1)]\} \qquad (3.5-2)$$

where N is the sample size.

Unlike the preferred G test, the basis for the traditional chi-square goodness-of-fit test is more intuitive than theoretical. Its test statistic is a measure of the difference between observed and expected cell frequencies, squared to get positive differences, expressed as proportions of the expected frequencies, and summed over all cells:

$$X^2 = (O_1-E_1)^2/E_1+\ldots+ (O_k-E_k)^2/E_k \qquad (3.5-3)$$

Like G, X^2 is approximately distributed as a chi-square variate with k-1-p degrees of freedom. Also, as in the G test, if $E_i < 5$, then cell i is commonly combined with a neighboring cell.

Both the G and chi-square tests for the goodness-of-fit have several advantages over the standard K-S test:

- they work well with discrete data,

- simple adjustments are available for intrinsic null hypotheses, and

- they are not as sensitive to serial correlation.

APPENDIX F

DESCRIPTION OF SAMPLE SIZE DETERMINATION

Several quick estimates of the required sample size can be obtained by employing approximations and simplifications. The first involves a general approach to sample size determination (Snedecor and Cochran, pp. 516-517). The key idea is to focus on a single point in the CDF rather than the entire CDF.

Let X be a statistic with standard deviation sd(X) and estimated value e(X). Then, with confidence 100*(1-a), a two-sided confidence interval for X may be approximated by:

$$[e(X)-Z_{a/2}*sd(X),\ e(X)+Z_{a/2}*sd(X)] \qquad (3.4\text{-}1)$$

where Z_q is the upper qth percentile of the standard normal distribution. If we can tolerate an error in e(X) of magnitude L or smaller, then Eq. (3.4-1) can be rewritten:

$$sd(X) <= L \ [illegible] \qquad (3.4\text{-}2)$$

Assuming that sd(X) in Eq. (3.4-2) can be expressed as a function of sample size N, we can solve for N and get an estimate of the required sample size.

For our purposes, let X inn Eq. (3.4-2) be the proportion P of the [illegible] with sky cover less than or equal to a specified threshold (ie., P is one point from the CDF). Thus P is given by either pA (from the BAA) of pL (from the BLA). We know (Lapin, p. 175) that the standard deviation of a proportion is given by:

$$sd(P) = [P*(1-P)/N]^{0.5} \qquad (3.4-3)$$

Substituting this expression for sd(P) in Eq. (3.4-2) and solving for sample size N yields:

$$N >= P*(1-P)*(Z_{a/2}/L)^2 \qquad (3.4-4)$$

The worst case (largest N) occurs for P=0.5. This is plausible since the two ends of a CDF are tied to values of 0 and 1 while between these limits much variation is possible. The discussion in Section 3 above suggests L and a should both be set to 0.05. Using these values of P, L, and a ($Z_{0.025}=1.96$), yields a minimum required sample size of approximately 385. So, this analysis indicates that a sample size of 450 is adequate while sample sizes of 150 and 300 are not. We conclude that we will need to use data from all three months of each season considered to reduce random sampling errors down to the level of anticipated model errors.

A second way to get a quick estimate of the required sample size is to look at the large sample asymptotic behavior of the critical values of the Kolmogorov-Smirnov (K-S) goodness-of-fit statistic D. Figure 3.4-1 provides a quick overview of this test statistic. D is defined to be the greatest absolute difference between the theoretical and empirical CDFs and thus D is a parameter of direct

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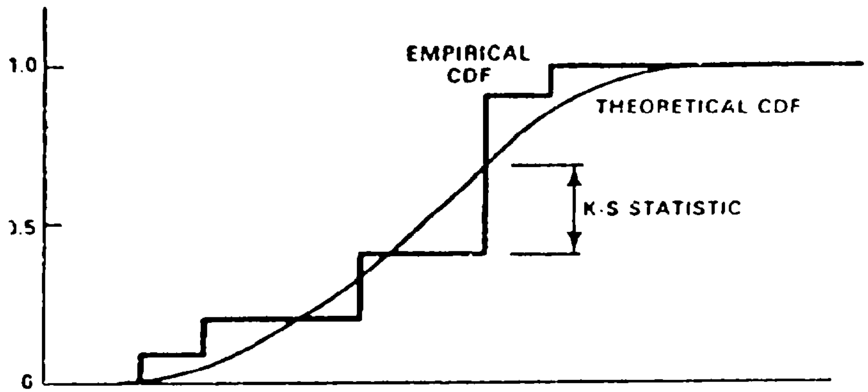
- DEFINED AS MAXIMUM ABSOLUTE DIFFERENCE BETWEEN THEORETICAL AND EMPIRICAL CUMULATIVE FREQUENCY DISTRIBUTIONS



- ASSUMES A CONTINUOUS VARIATE
- FOR EXTRINSIC HYPOTHESIS AND N > 30

$$D_{.05} = \frac{1.358}{\sqrt{N}} \qquad D = 0.05 \Rightarrow N = 738$$

- FOR INTRINSIC HYPOTHESIS AND N > 30

$$D_{0.05} = \frac{0.886}{\sqrt{N}} \qquad D = 0.05 \Rightarrow N = 314$$

Figure 3.4-1 The Kolmogorov-Smirnov Statistic interest and interpretation. For a sample size larger than 30 and the standard K-S test, an approximate 95 percent confidence critical value is given by (Rohlf and Sokal, p. 203):

$$D_{0.05} = 1.358\ N^{-0.5} <= L \qquad (3.4-5)$$

An estimate of the required sample size may be obtained by setting L equal to the error which can be tolerated in the CDF, in this case 0.05. Solving for N yields a minimum required sample size of about 738. This estimate is much larger than the previous one and is suspect because an important assumption of the K-S test is violated (Sokal and Rohlf, p 718).

The violated assumption, known as the extrinsic hypothesis, states that the parameters of the theoretical (model) distribution are known independently of the data at hand (ie., they are nor estimated from the same data used to compute the test statistic). The assumption is violated in this project because the same set of satellite scenes which are used to determine model parameters for each site, season, and time of day will be used to construct the empirical CDFs.

An alternate K-S test applicable with a normal populations and an intrinsic hypothesis (ie., the same data are used to estimate distribution parameters and construct the empirical CDF) was developed by Lilliefors. In his formulation, an approximate 95 percent confidence critical value is given by (Rohlf and Sokal, p. 206):

$$D_{0.05}=0.886\ N^{-0.5}<=L \qquad (3.4-6)$$

Again, an estimate of the required sample size may be obtained by setting L equal to 0.05. Solving for N yields a minimum required sample size of about 314. This is much closer to our first estimate of 385. We again conclude that sample of 150 and 300 are not adequate and that samples of 450 are adequate.

The assumption of a normal population in the preceding analysis is probably not valid. However, the actual shape of the underlying distribution probably would not impact our choice of 450 as sample size. Evidence for this assertion may be found in a paper by Crutcher. He presents expressions for the large sample asymptotic critical values for the K-S statistic which are valid with an intrinsic hypothesis and data from a wide range of distribution shapes (exponential, gamma, normal, and extreme value). The expressions for the 95 percent confidence critical values are all similar to Eqs. (3.4-5) and (3.4-6). The only difference is in the constant which ranges between 0.886 for a normal population and 1.06 for a particular exponential population. The latter constant value yields the largest sample size, namely 449. So again we conclude that a sample of 450 is adequate while samples of 150 and 300 are not.

APPENDIX G

ISOTROPY TEST RESULTS

This appendix presents the results from the isotropy tests in the form of histograms. The Histograms are presented below for all 12 sites along horizontal and vertical 316 km lines and represent isotropy of fractional sky cover and isotropy of maximum clear and cloudy runs. The anisotropy in the Florida data is evident. The histograms are arranged in the following format. Isotropy of fractional cloud cover along 316 km vertical (north-south) and horizontal (east-west) lines for winter 15, 18Z, summer 15, 18Z, and isotropy of maximum clear run and maximum cloudy runs for winter 15, 18Z, and summer 15, 18Z. All the tests for Florida are together, followed by all the isotropy tests for Kansas, and all the isotropy tests for Ohio.

```
Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record:  The Five Years From 1978 to 1982
Site:  Florida      Season:  Winter     Time of Day: 15


Horizontal Line:

 FREQ CUMF    % CUM%  CENTER  0.0     .050    .100    .150    .200    .250
 ---- ---- ---- ---- -------- +---+---+---+---+---+---+---+---+---+---+
   12   12    3    3            *****
   31   43    9   12   .150     **************
   42   85   12   24   .250     *******************
   37  122   10   34   .350     ****************
   33  155    9   43   .450     ***************
   36  191   10   53   .550     ****************
   35  226   10   63   .650     ****************
   24  250    7   69   .750     ***********
   26  276    7   76   .850     ************
   85  361   24  100            **************************************


Vertical Line:

 FREQ CUMF    % CUM%  CENTER  0.0     .050    .100    .150    .200    .250
 ---- ---- ---- ---- -------- +---+---+---+---+---+---+---+---+---+---+
   46   46   13   13            ********************
   45   91   12   25   .150     ********************
   28  119    8   33   .250     ************
   40  159   11   44   .350     ******************
   30  189    8   52   .450     *************
   35  224   10   62   .550     ****************
   21  245    6   68   .650     *********
   22  267    6   74   .750     **********
   33  300    9   83   .850     ***************
   61  361   17  100            ***************************


Two Sample KS Test for Equality of Distributions:
    Number of Cells =   20
    Sample Size = 361.
    Dmax =   .133   **
    Occurred at cell  4
    The difference (anisotropy) is significant at the 1% level.


Two Sample t-test for Equality of Means:
    Horizontal Line Mean and Standard Deviation:        .578      .298
    Vertical Line Mean and Standard Deviation:          .497      .321
    Sample Size = 361.
    t-Statistic =   3.514   **
    The difference (anisotropy) is significant at the 1% level.
```

Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Florida Season: Winter Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
144	144	40	40		**
87	231	24	64	60.0	************************
56	287	16	80	100.	****************
34	321	9	89	140.	*********
21	342	6	95	180.	******
11	353	3	98	220.	***
3	356	1	99	260.	*
5	361	1	100		*

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
99	99	27	27		***************************
86	185	24	51	60.0	************************
45	230	12	64	100.	************
46	276	13	76	140.	*************
25	301	7	83	180.	*******
30	331	8	92	220.	********
9	340	2	94	260.	**
21	361	6	100		******

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 361.
Dmax = .158 **
Occurred at cell 6
The difference (anisotropy) is significant at the 1% level.

Two Sample t-test for Equality of Means:

Horizontal Line Mean and Standard Deviation:	72.604	64.901
Vertical Line Mean and Standard Deviation:	102.355	84.743

Sample Size = 361.
t-Statistic = 5.296 **
The difference (anisotropy) is significant at the 1% level.

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Florida Season: Winter Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
92	92	25	25		*************************
82	174	23	48	60.0	***********************
36	210	10	58	100.	**********
41	251	11	70	140.	***********
24	275	7	76	180.	*******
18	293	5	81	220.	*****
11	304	3	84	260.	***
57	361	16	100		****************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
114	114	32	32		********************************
70	184	19	51	60.0	*******************
50	234	14	65	100.	**************
30	264	8	73	140.	********
22	286	6	79	180.	******
6	292	2	81	220.	**
25	317	7	88	260.	*******
44	361	12	100		************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 361.
Dmax = .091
Occurred at cell 1
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 123.573 102.028
Vertical Line Mean and Standard Deviation: 112.604 101.887
Sample Size = 361.
t-Statistic = 1.445
We cannot reject an hypothesis of equality (isotropy).

```
Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record:  The Five Years From 1978 to 1982
Site:  Florida     Season:  Winter     Time of Day: 18

Horizontal Line:

 FREQ CUMF    %  CUM%  CENTER   0.0    .060    .120    .180    .240    .300
 ---- ---- ---- ---- --------  +---+---+---+---+---+---+---+---+---+---+
   11   11    3    3             ****
   32   43    9   12    .150     ************
   38   81   11   23    .250     **************
   38  119   11   33    .350     **************
   30  149    8   42    .450     ***********
   39  188   11   53    .550     ***************
   27  215    8   60    .650     **********
   26  241    7   68    .750     **********
   26  267    7   75    .850     **********
   90  357   25  100             **********************************

Vertical Line:

 FREQ CUMF    %  CUM%  CENTER   0.0    .060    .120    .180    .240    .300
 ---- ---- ---- ---- --------  +---+---+---+---+---+---+---+---+---+---+
   46   46   13   13             *****************
   38   84   11   24    .150     **************
   41  125   11   35    .250     ***************
   33  158    9   44    .350     ************
   33  191    9   54    .450     ************
   19  210    5   59    .550     *******
   24  234    7   66    .650     *********
   26  260    7   73    .750     **********
   44  304   12   85    .850     ****************
   53  357   15  100             ********************

Two Sample KS Test for Equality of Distributions:
    Number of Cells =  20
    Sample Size = 357.
    Dmax =  .126  **
    Occurred at cell  5
    The difference (anisotropy) is significant at the 1% level.

Two Sample t-test for Equality of Means:
    Horizontal Line Mean and Standard Deviation:      .586      .302
    Vertical Line Mean and Standard Deviation:        .498      .325
    Sample Size = 357.
    t-Statistic =  3.756  **
    The difference (anisotropy) is significant at the 1% level.
```

```
Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record:  The Five Years From 1978 to 1982
Site:  Florida     Season:  Winter     Time of Day: 18


Horizontal Line:

 FREQ CUMF    % CUM%  CENTER   0.0    .100    .200    .300    .400    .500
 ---- ---- ---- ---- --------   +---+---+---+---+---+---+---+---+---+---+
  145  145   41   41             ********************************
   70  215   20   60   60.0      ****************
   54  269   15   75   100.      ************
   40  309   11   87   140.      *********
   27  336    8   94   180.      ******
   16  352    4   99   220.      ****
    1  353    0   99   260.
    4  357    1  100             *


Vertical Line:

 FREQ CUMF    % CUM%  CENTER   0.0    .100    .200    .300    .400    .500
 ---- ---- ---- ---- --------   +---+---+---+---+---+---+---+---+---+---+
   93   93   26   26             *********************
   76  169   21   47   60.0      *****************
   51  220   14   62   100.      ***********
   53  273   15   76   140.      ************
   30  303    8   85   180.      *******
   23  326    6   91   220.      *****
   12  338    3   95   260.      ***
   19  357    5  100             ****


Two Sample KS Test for Equality of Distributions:
    Number of Cells =  16
    Sample Size = 357.
    Dmax =  .148  **
    Occurred at cell  5
    The difference (anisotropy) is significant at the 1% level.


Two Sample t-test for Equality of Means:
    Horizontal Line Mean and Standard Deviation:     75.826    67.372
    Vertical Line Mean and Standard Deviation:      105.574    84.929
    Sample Size = 357.
    t-Statistic =  5.185  **
    The difference (anisotropy) is significant at the 1% level.
```

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Florida Season: Winter Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
86	86	24	24		************************
78	164	22	46	60.0	**********************
46	210	13	59	100.	*************
32	242	9	68	140.	*********
18	260	5	73	180.	*****
13	273	4	76	220.	****
11	284	3	80	260.	***
73	357	20	100		********************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
118	118	33	33		*********************************
60	178	17	50	60.0	*****************
49	227	14	64	100.	**************
25	252	7	71	140.	*******
21	273	6	76	180.	******
19	292	5	82	220.	*****
25	317	7	89	260.	*******
40	357	11	100		***********

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 357.
Dmax = .092
Occurred at 2 cells between 1 and 14
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 130.784 107.157
Vertical Line Mean and Standard Deviation: 114.706 101.916
Sample Size = 357.
t-Statistic = 2.054 *
The difference (anisotropy) is significant at the 5% level.

```
Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record:  The Five Years From 1979 to 1983
Site:  Florida      Season:  Summer     Time of Day: 15


Horizontal Line:

 FREQ CUMF    % CUM%  CENTER   0.0     .050    .100    .150    .200    .250
 ---- ---- ---- ---- --------   +---+---+---+---+---+---+---+---+---+---+
   36   36    9    9             **************
   80  116   20   29    .150     ********************************
   65  181   16   45    .250     **************************
   52  233   13   58    .350     *********************
   34  267    8   66    .450     *************
   26  293    6   73    .550     **********
   33  326    8   81    .650     *************
   22  348    5   86    .750     *********
   18  366    4   91    .850     *******
   38  404    9  100             ***************


Vertical Line:

 FREQ CUMF    % CUM%  CENTER   0.0     .050    .100    .150    .200    .250
 ---- ---- ---- ---- --------   +---+---+---+---+---+---+---+---+---+---+
   66   66   16   16             **************************
   84  150   21   37    .150     *********************************
   66  216   16   53    .250     **************************
   45  261   11   65    .350     ******************
   31  292    8   72    .450     ************
   36  328    9   81    .550     **************
   12  340    3   84    .650     *****
   14  354    3   88    .750     ******
   20  374    5   93    .850     ********
   30  404    7  100             ************


Two Sample KS Test for Equality of Distributions:
    Number of Cells =  20
    Sample Size = 404.
    Dmax =  .109  *
    Occurred at cell  5
    The difference (anisotropy) is significant at the 5% level.


Two Sample t-test for Equality of Means:
    Horizontal Line Mean and Standard Deviation:       .414      .281
    Vertical Line Mean and Standard Deviation:         .361      .279
    Sample Size = 404.
    t-Statistic =  2.676  **
    The difference (anisotropy) is significant at the 1% level.
```

Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Florida Season: Summer Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .060 .120 .180 .240 .300
100	100	25	25		*********************************
120	220	30	54	60.0	**
87	307	22	76	100.	*****************************
39	346	10	86	140.	*************
28	374	7	93	180.	*********
22	396	5	98	220.	*******
5	401	1	99	260.	**
3	404	1	100		*

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .060 .120 .180 .240 .300
65	65	16	16		*********************
112	177	28	44	60.0	*************************************
120	297	30	74	100.	**
51	348	13	86	140.	*****************
28	376	7	93	180.	*********
14	390	3	97	220.	*****
9	399	2	99	260.	***
5	404	1	100		**

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 404.
Dmax = .129 **
Occurred at cell 3
The difference (anisotropy) is significant at the 1% level.

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 87.129 62.928
Vertical Line Mean and Standard Deviation: 95.891 61.090
Sample Size = 404.
t-Statistic = 2.008 *
The difference (anisotropy) is significant at the 5% level.

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Florida Season: Summer Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .150 .300 .450 .600 .750
196	196	49	49		**************************
91	287	23	71	60.0	************
43	330	11	82	100.	******
20	350	5	87	140.	***
18	368	4	91	180.	**
10	378	2	94	220.	*
4	382	1	95	260.	*
22	404	5	100		***

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .150 .300 .450 .600 .750
215	215	53	53		****************************
78	293	19	73	60.0	**********
47	340	12	84	100.	******
17	357	4	88	140.	**
11	368	3	91	180.	*
8	376	2	93	220.	*
5	381	1	94	260.	*
23	404	6	100		***

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 404.
Dmax = .084
Occurred at cell 1
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 72.772 78.638
Vertical Line Mean and Standard Deviation: 68.020 79.577
Sample Size = 404.
t-Statistic = .854
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Florida Season: Summer Time of Day: 18

Horizontal Line:

```
 FREQ CUMF    % CUM%  CENTER   0.0     .050     .100     .150     .200     .250
 ---- ---- ---- ---- --------   +---+---+---+---+---+---+---+---+---+---+
    6    6    1    1            **
   37   43    9   10   .150     **************
   72  115   17   28   .250     ****************************
   57  172   14   41   .350     **********************
   52  224   13   54   .450     ********************
   40  264   10   64   .550     ***************
   38  302    9   73   .650     ***************
   36  338    9   81   .750     **************
   20  358    5   86   .850     ********
   57  415   14  100            **********************
```

Vertical Line:

```
 FREQ CUMF    % CUM%  CENTER   0.0     .050     .100     .150     .200     .250
 ---- ---- ---- ---- --------   +---+---+---+---+---+---+---+---+---+---+
   67   67   16   16            **************************
   90  157   22   38   .150     ***********************************
   53  210   13   51   .250     ********************
   41  251   10   60   .350     ****************
   33  284    8   68   .450     *************
   28  312    7   75   .550     ***********
   25  337    6   81   .650     **********
   25  362    6   87   .750     **********
   21  383    5   92   .850     ********
   32  415    8  100            ************
```

Two Sample KS Test for Equality of Distributions:
Number of Cells = 20
Sample Size = 415.
Dmax = .275 **
Occurred at cell 4
The difference (anisotropy) is significant at the 1% level.

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: .512 .267
Vertical Line Mean and Standard Deviation: .381 .290
Sample Size = 415.
t-Statistic = 6.756 **
The difference (anisotropy) is significant at the 1% level.

Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Florida Season: Summer Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
137	137	33	33		*********************************
122	259	29	62	60.0	*****************************
79	338	19	81	100.	*******************
47	385	11	93	140.	***********
22	407	5	98	180.	*****
8	415	2	100	220.	**
0	415	0	100	260.	
0	415	0	100		

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
76	76	18	18		******************
91	167	22	40	60.0	**********************
110	277	27	67	100.	***************************
72	349	17	84	140.	*****************
42	391	10	94	180.	**********
8	399	2	96	220.	**
7	406	2	98	260.	**
9	415	2	100		**

Two Sample KS .est for Equality of Distributions:
Number of Cells = 16
Sample Size = 415.
Dmax = .222 **
Occurred at 2 cells between 3 and 4
The difference (anisotropy) is significant at the 1% level.

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 71.831 51.962
Vertical Line Mean and Standard Deviation: 100.699 64.480
Sample Size = 415.
t-Statistic = 7.101 **
The difference (anisotropy) is significant at the 1% level.

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Florida Season: Summer Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
93	93	22	22		******************
150	243	36	59	60.0	*****************************
65	308	16	74	100.	*************
29	337	7	81	140.	******
21	358	5	86	180.	****
16	374	4	90	220.	***
7	381	2	92	260.	*
34	415	8	100		*******

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
207	207	50	50		**
67	274	16	66	60.0	*************
53	327	13	79	100.	**********
25	352	6	85	140.	*****
21	373	5	90	180.	****
12	385	3	93	220.	**
7	392	2	94	260.	*
23	415	6	100		****

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 415.
Dmax = .287 **
Occurred at cell 1
The difference (anisotropy) is significant at the 1% level.

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 98.964 83.131
Vertical Line Mean and Standard Deviation: 75.735 83.144
Sample Size = 415.
t-Statistic = 4.025 **
The difference (anisotropy) is significant at the 1% level.

Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Kansas Season: Winter Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
108	108	36	36		************************************
17	125	6	42	.150	******
19	144	6	48	.250	******
15	159	5	53	.350	*****
12	171	4	57	.450	****
13	184	4	61	.550	****
12	196	4	65	.650	****
10	206	3	69	.750	***
17	223	6	74	.850	******
77	300	26	100		**************************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
86	86	29	29		*****************************
22	108	7	36	.150	*******
19	127	6	42	.250	******
20	147	7	49	.350	*******
20	167	7	56	.450	*******
18	185	6	62	.550	******
15	200	5	67	.650	*****
12	212	4	71	.750	****
17	229	6	76	.850	******
71	300	24	100		************************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 20
Sample Size = 300.
Dmax = .073
Occurred at cell 2
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: .442 .394
Vertical Line Mean and Standard Deviation: .463 .374
Sample Size = 300.
t-Statistic = .669
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Kansas Season: Winter Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
103	103	34	34		**********************************
29	132	10	44	60.0	**********
24	156	8	52	100.	********
29	185	10	62	140.	**********
11	196	4	65	180.	****
11	207	4	69	220.	****
14	221	5	74	260.	*****
79	300	26	100		**************************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
95	95	32	32		********************************
29	124	10	41	60.0	**********
38	162	13	54	100.	*************
21	183	7	61	140.	*******
16	199	5	66	180.	*****
18	217	6	72	220.	******
17	234	6	78	260.	******
66	300	22	100		**********************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 300.
Dmax = .057
Occurred at cell 13
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 140.533 121.852
Vertical Line Mean and Standard Deviation: 138.200 115.944
Sample Size = 300.
t-Statistic = .240
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Kansas Season: Winter Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
144	144	48	48		*************************************
24	168	8	56	60.0	******
19	187	6	62	100.	*****
15	202	5	67	140.	****
21	223	7	74	180.	******
11	234	4	78	220.	***
13	247	4	82	260.	***
53	300	18	100		**************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
121	121	40	40		*******************************
39	160	13	53	60.0	**********
23	183	8	61	100.	******
20	203	7	68	140.	*****
12	215	4	72	180.	***
18	233	6	78	220.	*****
14	247	5	82	260.	****
53	300	18	100		**************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 300.
Dmax = .077
Occurred at cell 2
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 110.800 116.133
Vertical Line Mean and Standard Deviation: 117.333 114.557
Sample Size = 300.
t-Statistic = .694
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Kansas   Season: Winter   Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
86	86	29	29		*****************************
16	102	5	34	.150	*****
10	112	3	38	.250	***
17	129	6	43	.350	******
10	139	3	47	.450	***
11	150	4	50	.550	****
12	162	4	54	.650	****
21	183	7	61	.750	*******
17	200	6	67	.850	******
98	298	33	100		*********************************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
74	74	25	25		*************************
19	93	6	31	.150	******
18	111	6	37	.250	******
13	124	4	42	.350	****
13	137	4	46	.450	****
20	157	7	53	.550	*******
15	172	5	58	.650	*****
21	193	7	65	.750	*******
13	206	4	69	.850	****
92	298	31	100		*******************************

Two Sample KS Test for Equality of Distributions:
    Number of Cells = 20
    Sample Size = 298.
    Dmax = .050
    Occurred at cell 1
    We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
    Horizontal Line Mean and Standard Deviation: .528 .398
    Vertical Line Mean and Standard Deviation: .529 .382
    Sample Size = 298.
    t-Statistic = .026
    We cannot reject an hypothesis of equality (isotropy).

```
Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record:  The Five Years From 1978 to 1982
Site:  Kansas       Season:  Winter     Time of Day: 18

Horizontal Line:

 FREQ CUMF     % CUM%  CENTER  0.0     .080     .160     .240     .320     .400
 ---- ---- ---- ---- --------  +---+---+---+---+---+---+---+---+---+---+
  119  119   40   40            ****************************************
   38  157   13   53   60.0     *************
   21  178    7   60   100.     *******
   18  196    6   66   140.     ******
   19  215    6   72   180.     ******
    7  222    2   74   220.     **
   12  234    4   79   260.     ****
   64  298   21  100            *********************

Vertical Line:

 FREQ CUMF     % CUM%  CENTER  0.0     .080     .160     .240     .320     .400
 ---- ---- ---- ---- --------  +---+---+---+---+---+---+---+---+---+---+
  118  118   40   40            ****************************************
   37  155   12   52   60.0     ************
   20  175    7   59   100.     *******
   22  197    7   66   140.     *******
   24  221    8   74   180.     ********
   10  231    3   78   220.     ***
   11  242    4   81   260.     ****
   56  298   19  100            *******************

Two Sample KS Test for Equality of Distributions:
    Number of Cells =  16
    Sample Size = 298.
    Dmax =  .040
    Occurred at cell 15
    We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
    Horizontal Line Mean and Standard Deviation:     121.409    119.048
    Vertical Line Mean and Standard Deviation:       119.262    114.604
    Sample Size = 298.
    t-Statistic =   .224
    We cannot reject an hypothesis of equality (isotropy).
```

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Kansas Season: Winter Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
114	114	38	38		**************************************
28	142	9	48	60.0	*********
14	156	5	52	100.	*****
13	169	4	57	140.	****
11	180	4	60	180.	****
20	200	7	67	220.	*******
14	214	5	72	260.	*****
84	298	28	100		****************************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
106	106	36	36		************************************
24	130	8	44	60.0	********
23	153	8	51	100.	********
26	179	9	60	140.	*********
19	198	6	66	180.	******
7	205	2	69	220.	**
10	215	3	72	260.	***
83	298	28	100		****************************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 298.
Dmax = .067
Occurred at cell 9
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 142.685 126.614
Vertical Line Mean and Standard Deviation: 140.940 122.630
Sample Size = 298.
t-Statistic = .171
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Kansas Season: Summer Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
135	135	36	36		************************************
22	157	6	42	.150	******
17	174	5	47	.250	*****
21	195	6	52	.350	******
17	212	5	57	.450	*****
20	232	5	62	.550	*****
18	250	5	67	.650	*****
26	276	7	74	.750	*******
23	299	6	80	.850	******
74	373	20	100		********************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
132	132	35	35		***********************************
21	153	6	41	.150	******
21	174	6	47	.250	******
23	197	6	53	.350	******
15	212	4	57	.450	****
18	230	5	62	.550	*****
28	258	8	69	.650	********
18	276	5	74	.750	*****
28	304	8	82	.850	********
69	373	18	100		******************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 20
Sample Size = 373.
Dmax = .029
Occurred at cell 1
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: .430 .379
Vertical Line Mean and Standard Deviation: .428 .374
Sample Size = 373.
t-Statistic = .058
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Kansas Season: Summer Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
117	117	31	31		*******************************
43	160	12	43	60.0	************
26	186	7	50	100.	*******
22	208	6	56	140.	******
21	229	6	61	180.	******
21	250	6	67	220.	******
15	265	4	71	260.	****
108	373	29	100		*****************************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
104	104	28	28		****************************
47	151	13	40	60.0	*************
35	186	9	50	100.	*********
29	215	8	58	140.	********
18	233	5	62	180.	*****
24	257	6	69	220.	******
21	278	6	75	260.	******
95	373	25	100		*************************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 373.
Dmax = .038
Occurred at cell 13
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 149.464 121.389
Vertical Line Mean and Standard Deviation: 147.855 117.792
Sample Size = 373.
t-Statistic = .184
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Kansas Season: Summer Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
177	177	47	47		**************************************
42	219	11	59	60.0	*********
25	244	7	65	100.	*****
28	272	8	73	140.	******
22	294	6	79	180.	*****
20	314	5	84	220.	****
15	329	4	88	260.	***
44	373	12	100		*********

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
169	169	45	45		***********************************
40	209	11	56	60.0	*********
36	245	10	66	100.	********
23	268	6	72	140.	*****
22	290	6	78	180.	*****
14	304	4	82	220.	***
14	318	4	85	260.	***
55	373	15	100		************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 373.
Dmax = .046
Occurred at cell 13
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 99.062 105.466
Vertical Line Mean and Standard Deviation: 104.638 109.746
Sample Size = 373.
t-Statistic = .708
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Kansas Season: Summer Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
120	120	31	31		*******************************
31	151	8	39	.150	********
24	175	6	45	.250	******
18	193	5	50	.350	*****
18	211	5	55	.450	*****
20	231	5	60	.550	*****
28	259	7	67	.650	*******
19	278	5	72	.750	*****
28	306	7	79	.850	*******
80	386	21	100		*********************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
119	119	31	31		*******************************
31	150	8	39	.150	********
19	169	5	44	.250	*****
18	187	5	48	.350	*****
23	210	6	54	.450	******
18	228	5	59	.550	*****
25	253	6	66	.650	******
34	287	9	74	.750	*********
24	311	6	81	.850	******
75	386	19	100		*******************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 20
Sample Size = 386.
Dmax = .028
Occurred at cell 7
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: .449 .372
Vertical Line Mean and Standard Deviation: .453 .369
Sample Size = 386.
t-Statistic = .155
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Kansas Season: Summer Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
146	146	38	38		**************************************
44	190	11	49	60.0	***********
30	220	8	57	100.	********
23	243	6	63	140.	******
27	270	7	70	180.	*******
27	297	7	77	220.	*******
21	318	5	82	260.	*****
68	386	18	100		******************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
121	121	31	31		*******************************
57	178	15	46	60.0	***************
43	221	11	57	100.	***********
23	244	6	63	140.	******
15	259	4	67	180.	****
20	279	5	72	220.	*****
27	306	7	79	260.	*******
80	386	21	100		*********************

Two Sample KS Test for Equality of Distributions:
- Number of Cells = 16
- Sample Size = 386.
- Dmax = .065
- Occurred at cell 2
- We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
- Horizontal Line Mean and Standard Deviation: 125.440 112.935
- Vertical Line Mean and Standard Deviation: 133.782 115.748
- Sample Size = 386.
- t-Statistic = 1.013
- We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Kansas Season: Summer Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
184	184	48	48		**************************************
43	227	11	59	60.0	*********
28	255	7	66	100.	******
24	279	6	72	140.	*****
30	309	8	80	180.	******
17	326	4	84	220.	****
8	334	2	87	260.	**
52	386	13	100		***********

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
167	167	43	43		***********************************
46	213	12	55	60.0	**********
34	247	9	64	100.	*******
30	277	8	72	140.	******
22	299	6	77	180.	*****
22	321	6	83	220.	*****
14	335	4	87	260.	***
51	386	13	100		***********

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 386.
Dmax = .044
Occurred at cell 2
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 99.637 106.692
Vertical Line Mean and Standard Deviation: 104.922 107.036
Sample Size = 386.
t-Statistic = .687
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 Km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Ohio Season: Winter Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
43	43	14	14		***********
10	53	3	18	.150	***
16	69	5	23	.250	****
9	78	3	26	.350	**
12	90	4	30	.450	***
10	100	3	33	.550	***
16	116	5	39	.650	****
22	138	7	46	.750	******
25	163	8	54	.850	*******
137	300	46	100		*************************************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
35	35	12	12		*********
8	43	3	14	.150	**
13	56	4	19	.250	***
19	75	6	25	.350	*****
17	92	6	31	.450	*****
10	102	3	34	.550	***
24	126	8	42	.650	******
17	143	6	48	.750	*****
22	165	7	55	.850	******
135	300	45	100		************************************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 20
Sample Size = 300.
Dmax = .043
Occurred at cell 6
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: .671 .356
Vertical Line Mean and Standard Deviation: .678 .338
Sample Size = 300.
t-Statistic = .235
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Ohio Season: Winter Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .150 .300 .450 .600 .750
187	187	62	62		*********************************
27	214	9	71	60.0	*****
18	232	6	77	100.	***
19	251	6	84	140.	***
7	258	2	86	180.	*
6	264	2	88	220.	*
2	266	1	89	260.	
34	300	11	100		******

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .150 .300 .450 .600 .750
172	172	57	57		*******************************
41	213	14	71	60.0	*******
20	233	7	78	100.	****
10	243	3	81	140.	**
14	257	5	86	180.	**
14	271	5	90	220.	**
10	281	3	94	260.	**
19	300	6	100		***

Two Sample KS Test for Equality of Distributions:

Number of Cells = 16
Sample Size = 300.
Dmax = .053
Occurred at cell 15
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:

Horizontal Line Mean and Standard Deviation: 74.733 98.715
Vertical Line Mean and Standard Deviation: 73.200 92.185
Sample Size = 300.
t-Statistic = .197
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Ohio Season: Winter Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
69	69	23	23		***********************
33	102	11	34	60.0	***********
22	124	7	41	100.	*******
26	150	9	50	140.	*********
23	173	8	58	180.	********
18	191	6	64	220.	******
8	199	3	66	260.	***
101	300	34	100		**********************************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .080 .160 .240 .320 .400
55	55	18	18		******************
30	85	10	28	60.0	**********
35	120	12	40	100.	************
27	147	9	49	140.	*********
22	169	7	56	180.	*******
19	188	6	63	220.	******
13	201	4	67	260.	****
99	300	33	100		*********************************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 300.
Dmax = .070
Occurred at cell 3
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 167.467 119.470
Vertical Line Mean and Standard Deviation: 174.200 114.218
Sample Size = 300.
t-Statistic = .706
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Ohio Season: Winter Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .150 .300 .450 .600 .750
35	35	11	11		******
9	44	3	14	.150	**
7	51	2	16	.250	*
15	66	5	21	.350	***
14	80	4	25	.450	**
21	101	7	32	.550	****
20	121	6	38	.650	***
10	131	3	41	.750	**
25	156	8	49	.850	****
162	318	51	100		***************************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .150 .300 .450 .600 .750
32	32	10	10		*****
7	39	2	12	.150	*
11	50	3	16	.250	**
11	61	3	19	.350	**
23	84	7	26	.450	****
15	99	5	31	.550	***
13	112	4	35	.650	**
24	136	8	43	.750	****
27	163	8	51	.850	*****
155	318	49	100		**************************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 20
Sample Size = 318.
Dmax = .028
Occurred at 2 cells between 14 and 17
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: .712 .332
Vertical Line Mean and Standard Deviation: .713 .325
Sample Size = 318.
t-Statistic = .066
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Ohio Season: Winter Time of Day: 18

Horizontal Line:

```
FREQ CUMF    %  CUM%  CENTER   0.0     .150     .300     .450     .600     .750
---- ---- ---- ---- --------   +---+---+---+---+---+---+---+---+---+---+
 206  206   65   65              ***********************************
  31  237   10   75    60.0      *****
  26  263    8   83    100.      ****
  16  279    5   88    140.      ***
  10  289    3   91    180.      **
   1  290    0   91    220.
   6  296    2   93    260.      *
  22  318    7  100              ****
```

Vertical Line:

```
FREQ CUMF    %  CUM%  CENTER   0.0     .150     .300     .450     .600     .750
---- ---- ---- ---- --------   +---+---+---+---+---+---+---+---+---+---+
 193  193   61   61              ********************************
  39  232   12   73    60.0      *******
  23  255    7   80    100.      ****
  19  274    6   86    140.      ***
  14  288    4   91    180.      **
   8  296    3   93    220.      *
   5  301    2   95    260.      *
  17  318    5  100              ***
```

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 318.
Dmax = .050
Occurred at cell 1
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 61.006 86.361
Vertical Line Mean and Standard Deviation: 64.591 84.665
Sample Size = 318.
t-Statistic = .529
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1978 to 1982
Site: Ohio Season: Winter Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
56	56	18	18		**************
33	89	10	28	60.0	********
27	116	8	36	100.	*******
22	138	7	43	140.	******
20	158	6	50	180.	*****
22	180	7	57	220.	******
14	194	4	61	260.	****
124	318	39	100		*******************************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
53	53	17	17		*************
20	73	6	23	60.0	*****
33	106	10	33	100.	********
24	130	8	41	140.	******
22	152	7	48	180.	******
17	169	5	53	220.	****
20	189	6	59	260.	*****
129	318	41	100		********************************

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 318.
Dmax = .066
Occurred at cell 5
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 185.031 118.398
Vertical Line Mean and Standard Deviation: 192.767 114.918
Sample Size = 318.
t-Statistic = .836
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Ohio Season: Summer Time of Day: 15

Horizontal Line:

```
FREQ CUMF    % CUM%  CENTER   0.0     .080     .160     .240     .320     .400
---- ---- ---- ---- --------  +---+---+---+---+---+---+---+---+---+----+
  93   93   26   26            **************************
  33  126    9   35   .150     *********
  11  137    3   38   .250     ***
  19  156    5   43   .350     *****
  15  171    4   47   .450     ****
  10  181    3   50   .550     ***
  22  203    6   56   .650     ******
  18  221    5   61   .750     *****
  25  246    7   68   .850     *******
 118  364   32  100            ********************************
```

Vertical Line:

```
FREQ CUMF    % CUM%  CENTER   0.0     .080     .160     .240     .320     .400
---- ---- ---- ---- --------  +---+---+---+---+---+---+---+---+---+----+
  78   78   21   21            *********************
  26  104    7   29   .150     *******
  17  121    5   33   .250     *****
  30  151    8   41   .350     ********
  19  170    5   47   .450     *****
  16  186    4   51   .550     ****
  25  211    7   58   .650     *******
  31  242    9   66   .750     *********
  28  270    8   74   .850     ********
  94  364   26  100            **************************
```

Two Sample KS Test for Equality of Distributions:
Number of Cells = 20
Sample Size = 364.
Dmax = .069
Occurred at cell 17
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:

Horizontal Line Mean and Standard Deviation:	.529	.393
Vertical Line Mean and Standard Deviation:	.529	.364

Sample Size = 364.
t-Statistic = .024
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Ohio Season: Summer Time of Day: 15

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
154	154	42	42		**********************************
35	189	10	52	60.0	********
27	216	7	59	100.	******
23	239	6	66	140.	*****
26	265	7	73	180.	******
22	287	6	79	220.	*****
13	300	4	82	260.	***
64	364	18	100		**************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .100 .200 .300 .400 .500
131	131	36	36		*****************************
56	187	15	51	60.0	************
41	228	11	63	100.	*********
24	252	7	69	140.	*****
21	273	6	75	180.	*****
25	298	7	82	220.	*****
14	312	4	86	260.	***
52	364	14	100		***********

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 364.
Dmax = .077
Occurred at cell 1
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 117.747 114.225
Vertical Line Mean and Standard Deviation: 114.121 107.111
Sample Size = 364.
t-Statistic = .442
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Ohio Season: Summer Time of Day: 15

Horizontal Line:

```
FREQ CUMF    %  CUM%  CENTER   0.0     .080     .160     .240     .320     .400
---- ---- ---- ---- --------   +---+---+---+---+---+---+---+---+---+---+
 133  133   37   37             *************************************
  31  164    9   45    60.0     *********
  35  199   10   55    100.     **********
  27  226    7   62    140.     *******
  25  251    7   69    180.     *******
  21  272    6   75    220.     ******
  15  287    4   79    260.     ****
  77  364   21  100             *********************
```

Vertical Line:

```
FREQ CUMF    %  CUM%  CENTER   0.0     .080     .160     .240     .320     .400
---- ---- ---- ---- --------   +---+---+---+---+---+---+---+---+---+---+
 114  114   31   31             *******************************
  44  158   12   43    60.0     ************
  41  199   11   55    100.     ***********
  31  230    9   63    140.     *********
  24  254    7   70    180.     *******
  21  275    6   76    220.     ******
  18  293    5   80    260.     *****
  71  364   20  100             ********************
```

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 364.
Dmax = .052
Occurred at cell 2
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 130.824 116.545
Vertical Line Mean and Standard Deviation: 132.198 112.794
Sample Size = 364.
t-Statistic = .162
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Fractional Sky Cover
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Ohio Season: Summer Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .060 .120 .180 .240 .300
33	33	8	8		***********
23	56	6	14	.150	********
20	76	5	19	.250	*******
29	105	7	26	.350	**********
30	135	8	34	.450	**********
43	178	11	45	.550	**************
30	208	8	52	.650	**********
41	249	10	62	.750	**************
33	282	8	71	.850	***********
118	400	30	100		***************************************

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .060 .120 .180 .240 .300
26	26	7	7		*********
24	50	6	13	.150	********
23	73	6	18	.250	********
38	111	10	28	.350	*************
36	147	9	37	.450	************
34	181	9	45	.550	***********
39	220	10	55	.650	*************
42	262	11	66	.750	**************
37	299	9	75	.850	************
101	400	25	100		**********************************

Two Sample KS Test for Equality of Distributions:
    Number of Cells = 20
    Sample Size = 400.
    Dmax = .043
    Occurred at 2 cells between 18 and 19
    We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
    Horizontal Line Mean and Standard Deviation: .622 .312
    Vertical Line Mean and Standard Deviation: .612 .299
    Sample Size = 400.
    t-Statistic = .481
    We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Clear Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Ohio Season: Summer Time of Day: 18

Horizontal Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .150 .300 .450 .600 .750
233	233	58	58		***************************************
70	303	18	76	60.0	*********
26	329	7	82	100.	***
25	354	6	89	140.	***
10	364	3	91	180.	*
13	377	3	94	220.	**
8	385	2	96	260.	*
15	400	4	100		**

Vertical Line:

FREQ	CUMF	%	CUM%	CENTER	0.0 .150 .300 .450 .600 .750
208	208	52	52		****************************
73	281	18	70	60.0	**********
43	324	11	81	100.	******
30	354	8	89	140.	****
14	368	4	92	180.	**
9	377	2	94	220.	*
15	392	4	98	260.	**
8	400	2	100		*

Two Sample KS Test for Equality of Distributions:
Number of Cells = 16
Sample Size = 400.
Dmax = .068
Occurred at cell 1
We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
Horizontal Line Mean and Standard Deviation: 62.950 77.358
Vertical Line Mean and Standard Deviation: 66.600 73.279
Sample Size = 400.
t-Statistic = .685
We cannot reject an hypothesis of equality (isotropy).

Isotropy of Longest Cloudy Run
Along Horizontal and Vertical 316 km Lines
Analysis Date: 88/08/17
Period of Record: The Five Years From 1979 to 1983
Site: Ohio Season: Summer Time of Day: 18

Horizontal Line:

```
FREQ CUMF    % CUM%  CENTER   0.0     .080     .160     .240     .320     .400
---- ---- ---- ---- -------- +---+---+---+---+---+---+---+---+---+---+
 135  135   34   34           **********************************
  56  191   14   48   60.0    **************
  37  228    9   57   100.    *********
  32  260    8   65   140.    ********
  28  288    7   72   180.    *******
  25  313    6   78   220.    ******
  16  329    4   82   260.    ****
  71  400   18  100           ******************
```

Vertical Line:

```
FREQ CUMF    % CUM%  CENTER   0.0     .080     .160     .240     .320     .400
---- ---- ---- ---- -------- +---+---+---+---+---+---+---+---+---+---+
 111  111   28   28           ****************************
  64  175   16   44   60.0    ****************
  48  223   12   56   100.    ************
  41  264   10   66   140.    **********
  29  293    7   73   180.    *******
  22  315    6   79   220.    ******
  23  338    6   85   260.    ******
  62  400   16  100           ****************
```

Two Sample KS Test for Equality of Distributions:
    Number of Cells = 16
    Sample Size = 400.
    Dmax = .060
    Occurred at cell 2
    We cannot reject an hypothesis of equality (isotropy).

Two Sample t-test for Equality of Means:
    Horizontal Line Mean and Standard Deviation: 126.450 109.866
    Vertical Line Mean and Standard Deviation: 129.000 104.443
    Sample Size = 400.
    t-Statistic = .336
    We cannot reject an hypothesis of equality (isotropy).

APPENDIX H

DESCRIPTION OF SIMULATION STUDIES

A. PROCEDURE

The purpose of the simulation studies was to determine the critical values for the goodness-of-fit hypothesis tests. It is necessary to produce a simulation since the exact critical values are own.

The first step in this procedure was to construct a random sample of Po (mean clear) and r (scale distance). This was done for all three sites, two seasons, and two times of day for random samples from the largest area empirical distribution. One hundred simple random samples (with replacement) were selected, and Po was computed and r was estimated using the AFGL scale distance algorithm. These samples each contained the same number of observations as the original.

The next step was to generate distributions of the four goodness-of-fit statistics: Anderson Darling, Kolmogorov-Smirnov, Pearson Chi-Square, and Log Likelihood Ratio. This was done for each of three sites, two seasons, two times of day; for both the area algorithm and the two (east-west and north-south) line algorithms; and for each of five lengths or areas. Out of a possible 100 pairs of Po and r generated above, ten were used. For each of the ten, a BAA or BLA distribution was generated. For each of these distributions, the following was done:

1. Constructed simulated distributions of cloud cover by randomly sampling from the BAA/BLA produced distribution. These samples should be similar, but display a degree of natural variation.

2. Computed and saved goodness-of-fit statistics between these simulated distributions and the BAA/BLA produced distribution, to capture this variability.

We now had 300 sets (10 pairs of Po, r times 30 simulated empirical distributions) of values for each of the four goodness-of-fit statistics. The values were placed in ascending order, and the 95th percentile was determined. This was the estimate of the critical value.

There are two areas where decisions critical to the outcome of this procedure are made. The first is the required total number of samples, here 300. The second, the method of simulating empirical distributions. These are addressed below.

B. MONTE CARLO EMPIRICAL DISTRIBUTIONS

There were several procedures considered:

1. Draw a simple random sample (with replacement) from the empirical distribution. This was computationally inexpensive, but ignored serial correlation. It was performed for all 180 datasets.

2. Fit Markov chain to the empirical distributions. Draw random samples by sampling from the appropriate row of the transition matrix. This accounts for serial correlation and does not require variable transformation. However, because of missing data, not all transitions are known and consequently, not all of the data can be used. It has the further disadvantage of imposing a model. It was performed for a selected group of 32 datasets.

3. Fit a Markov chain as above. Draw simple random samples from the steady state probability vector. (The transition matrix raised to the nth power, in the limit where n approaches infinity). This method differs from 2 in that it introduces simple random sampling. It was performed on the same 32 datasets to give an idea of the biases introduced in 1, the principal method. These biases were then removed.

Two procedures were rejected outright:

4. Fit an ARMA model to the satellite empirical distributions. Draw a random sample from the fitted ARMA model. This accounts for serial correlation but imposes a model. Also ARMA modeling requires that the error variance be constant over the full range of sky cover (0 to 1). The variance was found to vary indicating the need for transformation of variables. The main culprit was the categorical nature of the data (20 bins, sometimes far fewer, e.g., 10-km lines). Unique transformations were required for most time series (three sites, x two times x two seasons x five lengths x three variables = 180 time series). Finding custom transformations was deemed to be too expensive so this approach was rejected.

5. Draw a random sample by randomly selecting multi-day segments from the empirical time series. This is attractive because it is simple, inexpensive, accounts for serial correlation, and does not impose a model. Unfortunately, there is no way to include the effect of sampling on the choice of parameters (Po and r). Consequently, this method was rejected.

C. MONTE CARLO SAMPLE SIZE

The required sample size is a function of the accuracy required. This in turn is a function of how close the computed goodness-of-fit statistics are to the estimated critical values. If they are approximately equal, fairly accurate critical values are required. Otherwise, less accurate estimates should suffice.

We need to gauge the accuracy of the estimated 95 percentiles. To do this, we also estimate 95% confidence intervals for the point estimates.

Let I = [p-dp, p + dp] be a 95% confidence interval (i.e., significance a=0.05) for binomial parameter p. Using a normal approximation

$$dp = \left(\frac{p(1-p)}{N}\right)^{1/2} \cdot Z \quad a/2$$

For a = 0.05. p = 0.95, Z a/2 = 1.96, and 95% confidence limit of normal distribution we have

$$dp = \frac{0.427}{\sqrt{N}}$$

The table below shows various values of p and I for various sample sizes.

N	dp	I	
30	0.078	[0.872,1.000]*	Normal Approx Marginal
100	0.043	[0.907,0.993]	(N=100) or Poor N=30)
300	0.025	[0.925,0.975]	
1000	0.014	[0.936,0.964]	
3000	0.008	[0.942,0.958]	Normal Approx. Adequate
10000	0.004	[0.946,0.954]	
30000	0.002	[0.948,0.952]	

To find the 95 percentile and its 95% confidence interval, we find:

1. Goodness-of-Fit Order Statistics:

   $X(1) \leq X(2) \leq \ldots \leq X(N)$ X<--(A,D,G,X)

2. Critical Value

   X0.95 = X(ROUND[0.95(N+1])

3. Confidence Intervals

   I = [x(FLOOR[(0.95- p)(N+1)]), X(CEILING[(0.95+ P)(N+1)].

where for $y>0$ FLOOR(y) = TRUNC(y)

CEILING(y) = TRUNC(y) if y = TRUNC(y)

1+TRUNC(y) otherwise

TRUNC(y) = integer part of y

To gauge the required Monte Carlo sample size, a pilot study was done. It used the area variable only (i.e., BAA), the 15Z winter Florida $(10\ km)^2$ data set, and sample sizes of 30, 90, 300, 450, 600, 750, and 900. Method 1 was used to draw empirical Monte Carlo samples. The table on the next page summarizes the results.

BAA, 15Z, FLORIDA, WINTER, $(10\ km)^2$ AREA

Anderson Darling Statistic Results: Actual = 15.95

N	CVL	CV	CVU
30	1.30	--	1.63
90	1.28	--	2.42
300	1.46	1.64	2.10
450	1.50	1.65	2.02
600	1.57	1.76	2.02
750	1.63	1.79	2.06
900	1.64	1.79	2.02

Kolmogorov-Smirnov Statistic Results: Actual = 0.154

N	CVL	CV	CVU
30	0.055	--	0.058
90	0.049	--	0.063
300	0.051	0.056	0.061
450	0.052	0.056	0.060
600	0.052	0.055	0.060
750	0.053	0.056	0.060
900	0.053	0.056	0.060

Pearson Chi Square Statistic Results: Actual = 934.65

	CVL	CV	CVU
30	6.27	--	13.84
90	6.12	--	14.41
300	6.97	8.69	13.61
450	7.74	8.63	10.32
600	7.73	8.63	9.91
750	7.65	8.61	9.85
900	7.56	8.50	9.07

Log Likelihood Ratio Statistic Results: Actual = 357.55

	CVL	CV	CVU
30	6.92	--	12.71
90	6.72	--	12.71
300	7.07	7.97	10.57
450	7.66	8.09	10.15

600	7.56	8.00	9.95
750	7.51	7.97	9.74
900	7.45	7.96	8.83

Here, the critical value upper (CVU) and lower CVL) bounds as well as the point estimate (CV) are shown. The actual result obtained from the actual (observed) distribution is included. In this case, the result of the goodness-of-fit test was clear using any of the sample sizes.

Using an IBM PC/AT compatible, Method 1, and all data sets, the following estimates for time to complete the simulations was developed:

N	Estimated Simulation Time
30	1.5 hr
100	5.0 hr
300	15 hr
1000	50 hr = 2+ days
3000	150 hr = 6.25 days

There is a diminishing benefit of increased sample sizes. Large sample sizes are prohibitively expensive. Large sample sizes and high accuracy are not required since actual goodness-of-fit statistics are usually much larger than critical value upper bounds. We therefore used N=300 as a reasonable compromise among desired accuracy and cost.

APPENDIX I

HISTOGRAMS OF MODEL AND EMPIRICAL FREQUENCY DISTRIBUTIONS

This appendix contains the histograms for all 12 BAA files (each page contains all 5 areas) and all 12 BLA files (each page contains all 5 vertical and horizontal lines). The files are arranged in the following format:

15Z Florida Winter
18Z Florida Winter
15Z Florida Summer
18Z Florida Summer
15Z Kansas Winter
18Z Kansas Winter
15Z Kansas Summer
18Z Kansas Summer
15Z Ohio Winter
18Z Ohio Winter
15Z Ohio Summer
18Z Ohio Summer

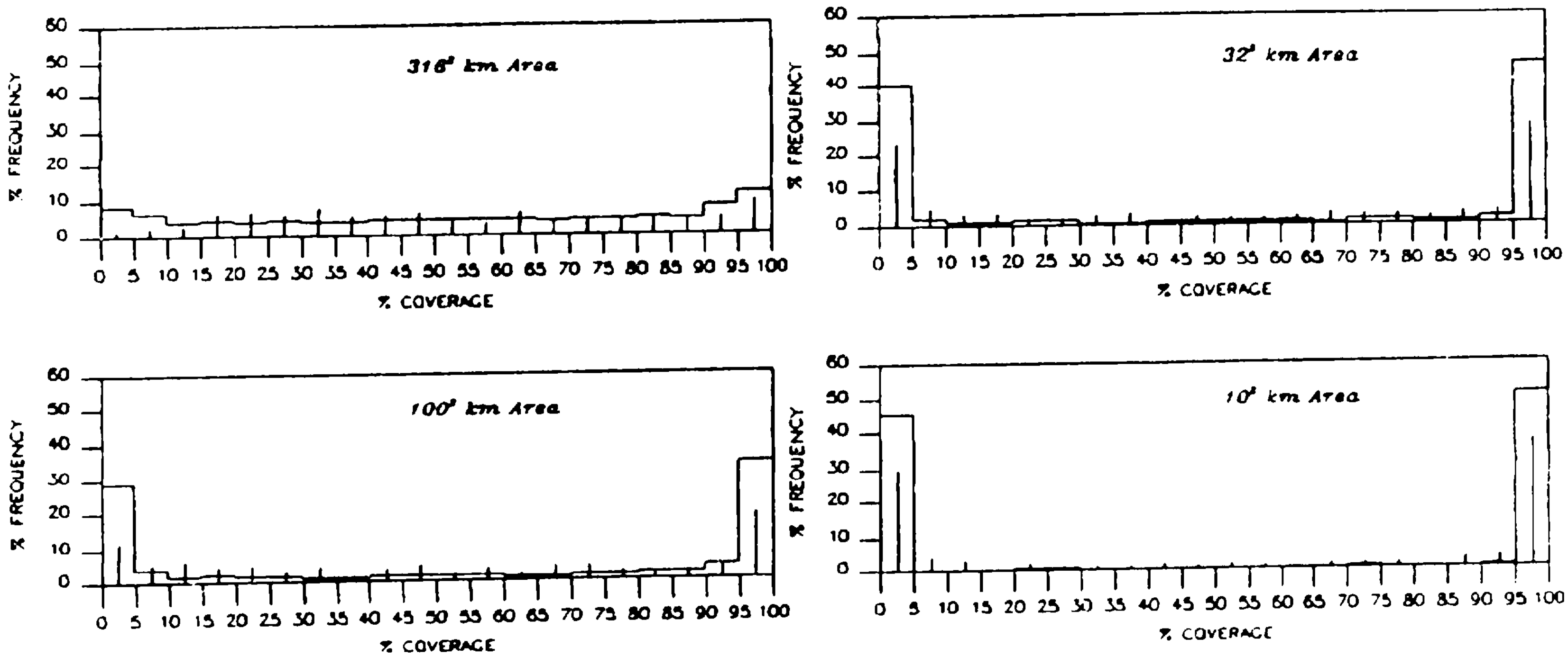
There are 5 histograms per page [representing the 5 areas]. The BLA histograms are arranged in the same format as the BAA histograms. There are BLA histograms per page representing the 5 lines (horizontal and vertical lines are on same graph).

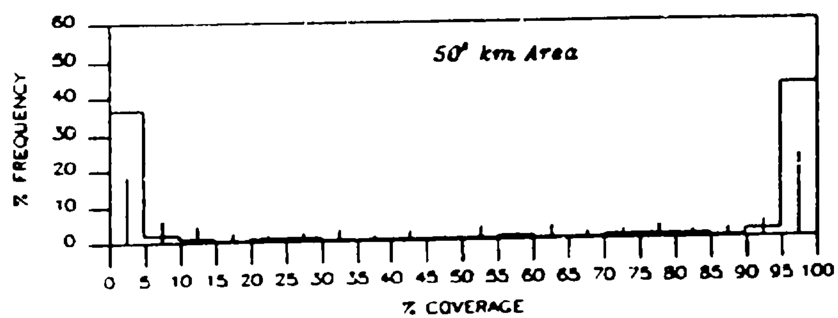
After inspecting the tables, many of the results we have presented are clearly evident. The model bias (overprediction extremes of clouds (5%-95%)) stand out in many of the histograms. Finally, in many cases the general shape of the distributions agree fairly well, especially for the Kansas and Ohio cases.

AREAL SKY COVER

Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

FL 15Z Dec-Feb, 1979-83





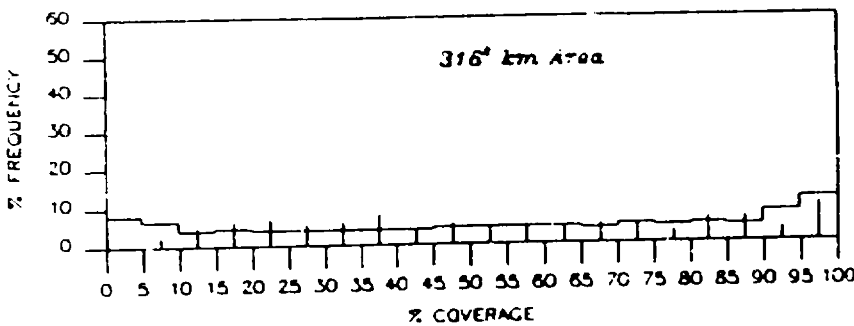
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 4.70 km
Sample size ' = 361 cases

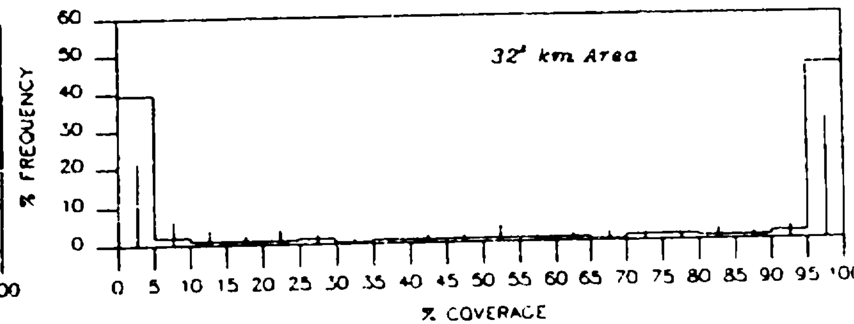
' Computed from Emperical Distributions for 316² Area

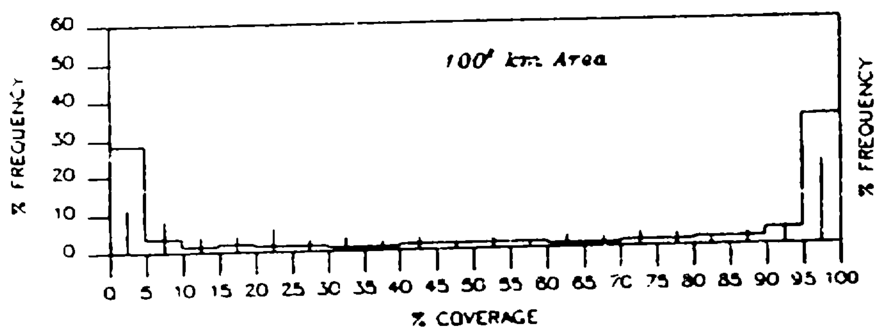
AREAL SKY COVER

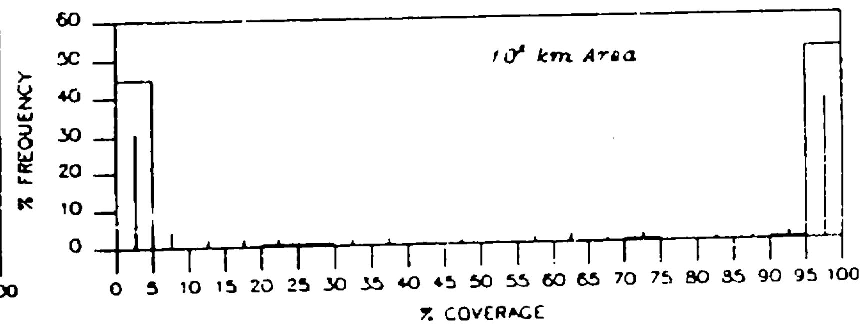
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

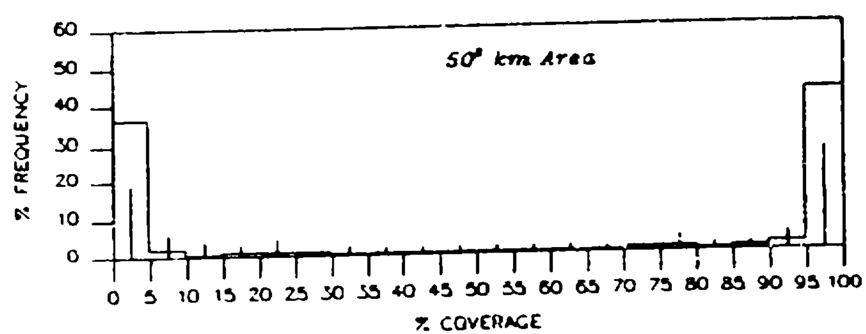
FL 18Z Dec-Feb, 1979-83











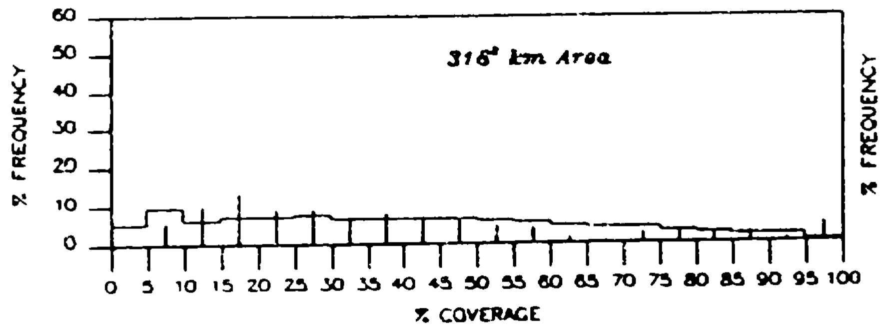
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 4.61 km
Sample size ' = 357 cases

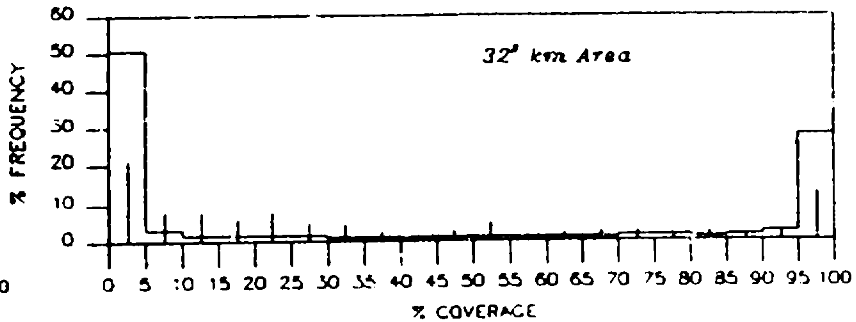
' *Computed from Emperical Distributions for 316² Area*

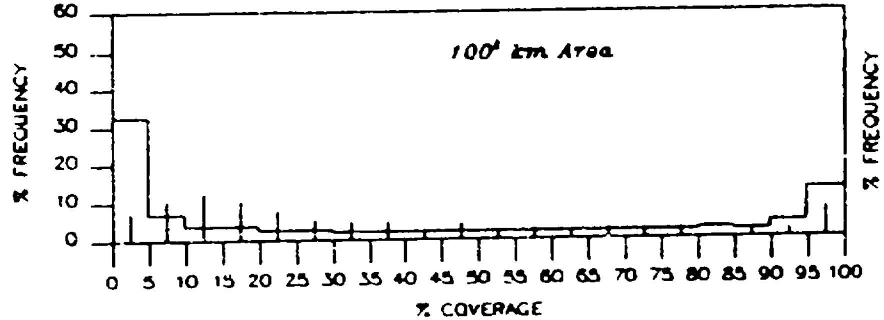
AREAL SKY COVER

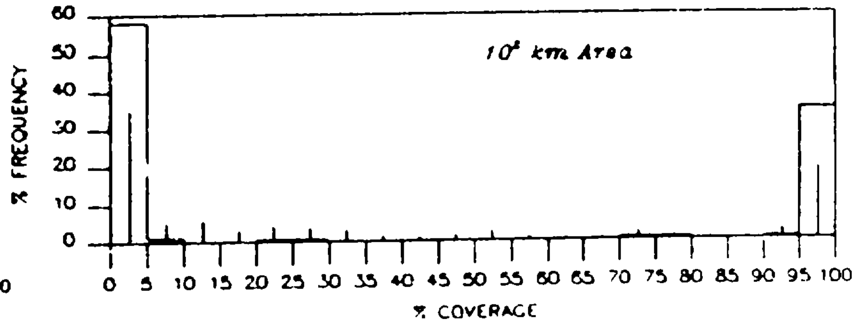
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

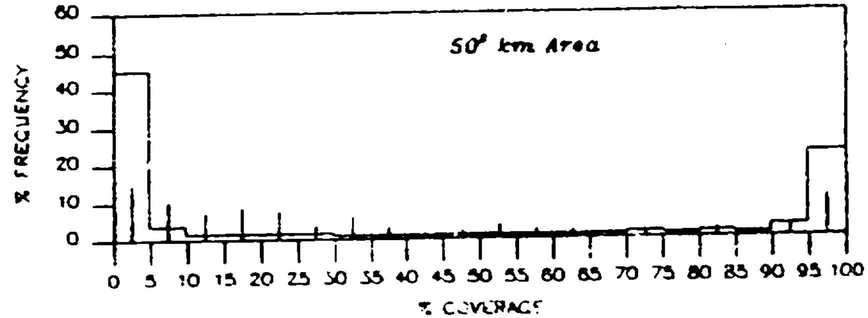
FL 15Z Jun-Aug, 1979-83











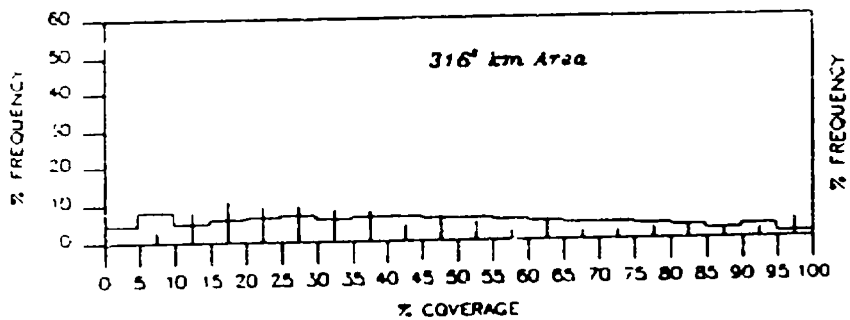
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 2.66 km
Sample size ' = 404 cases

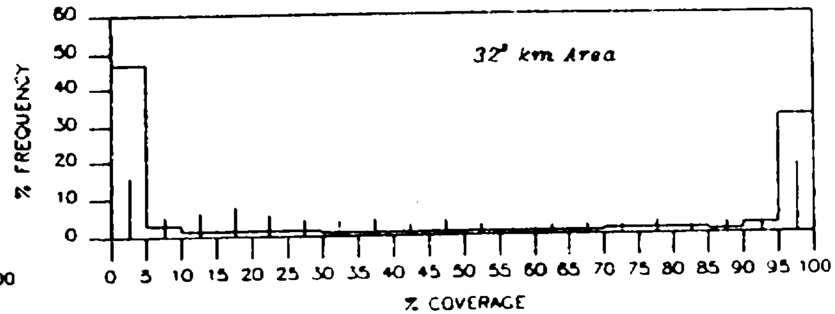
' Computed from Emperical Distributions for 316² Area

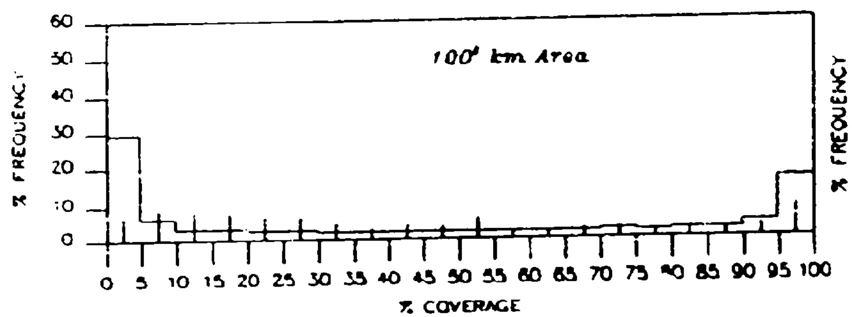
AREAL SKY COVER

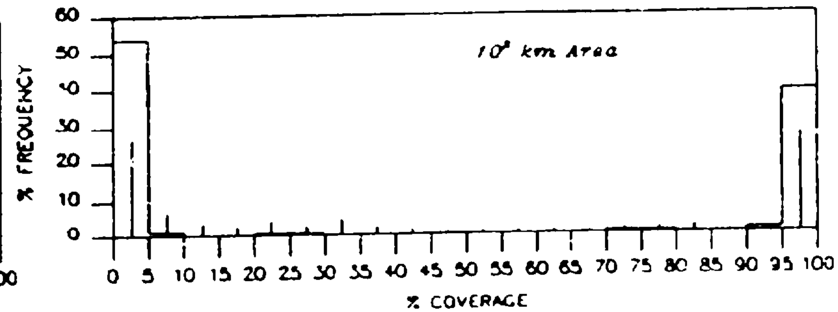
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

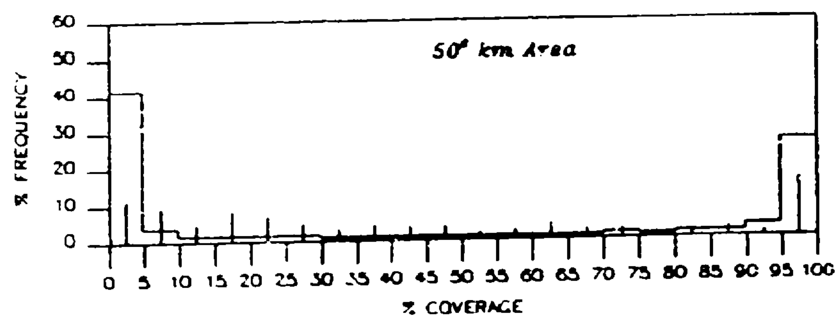
FL 18Z Jun-Aug, 1979-83











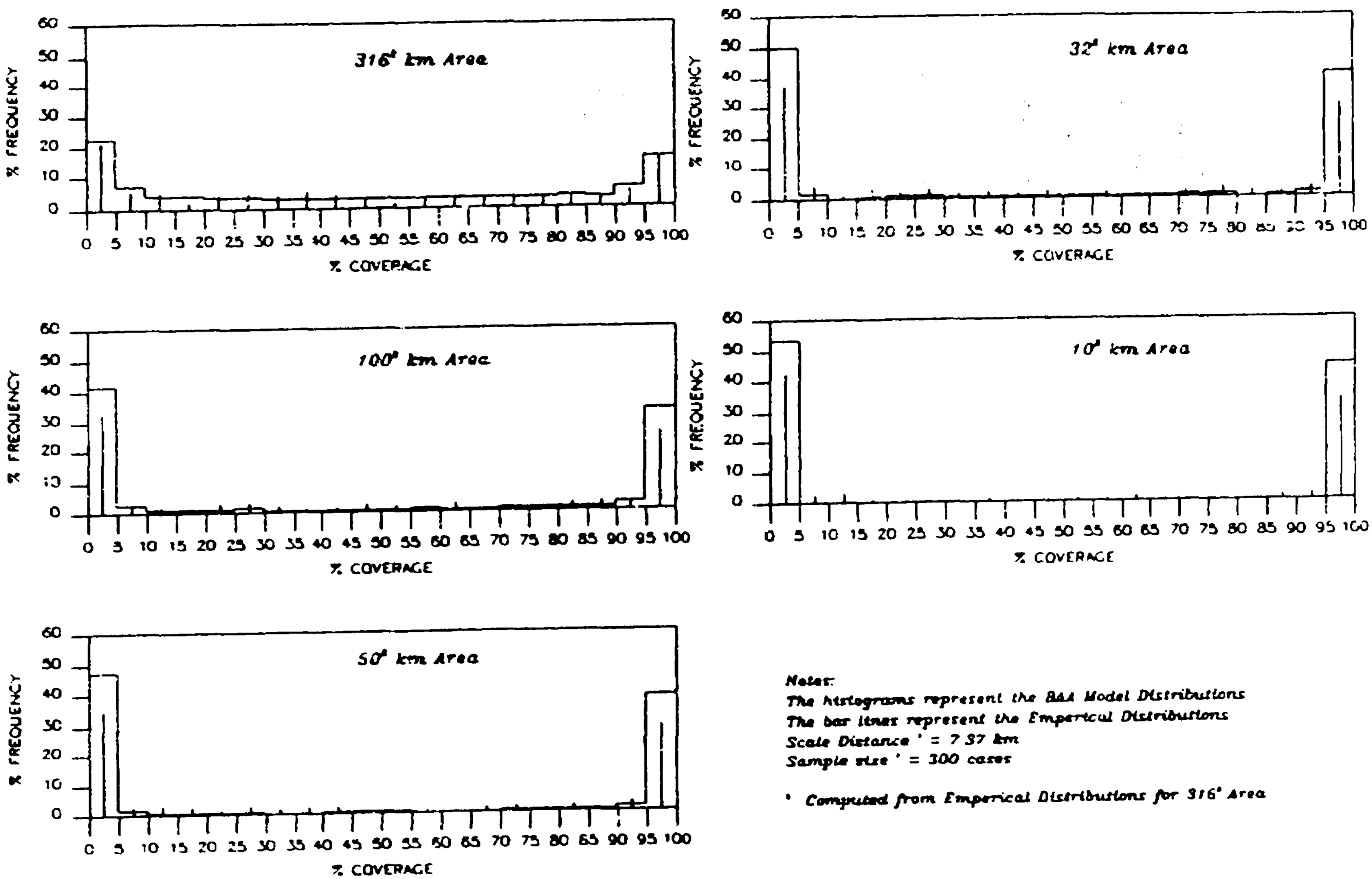
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 2.80 km
Sample size ' = 415 cases

' *Computed from Emperical Distributions for 316² Area*

AREAL SKY COVER

Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

KS 15Z Dec-Feb, 1979-83



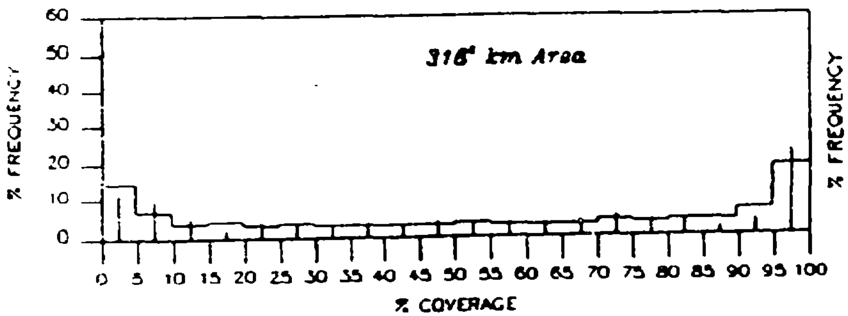
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 7.37 km
Sample size ' = 300 cases

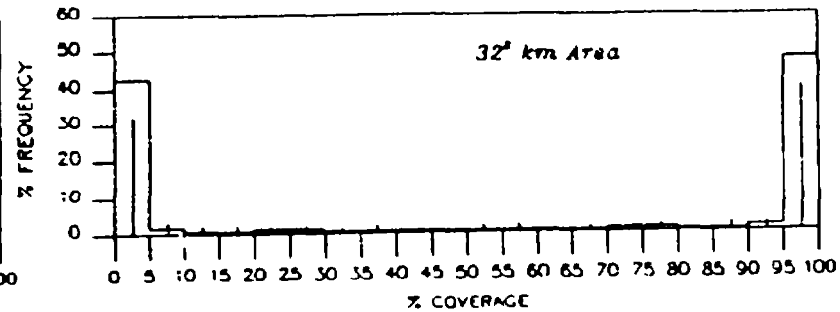
' *Computed from Emperical Distributions for 316² Area*

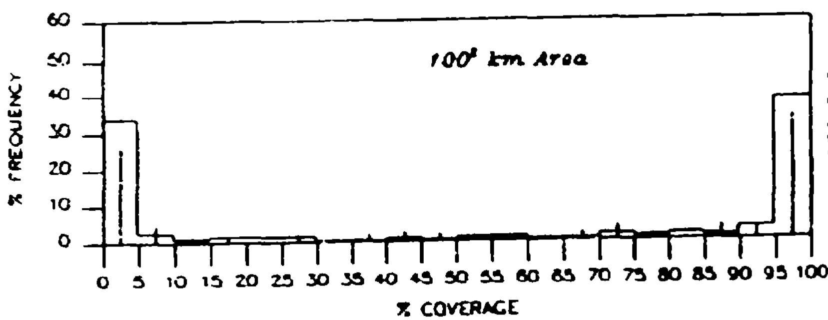
AREAL SKY COVER

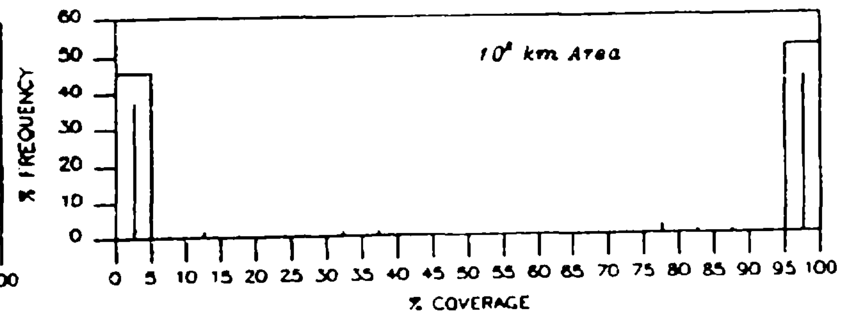
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

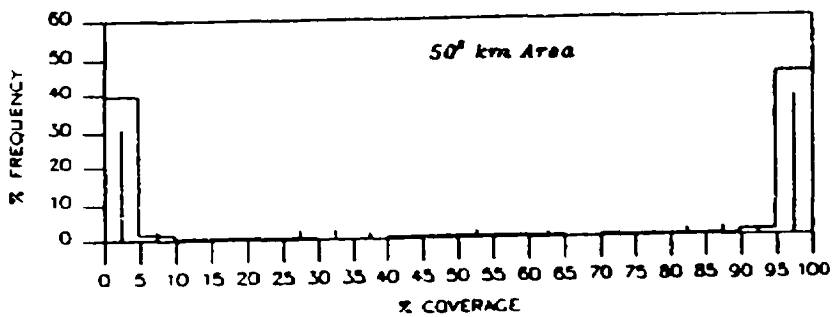
KS 18Z Dec–Feb, 1979–83











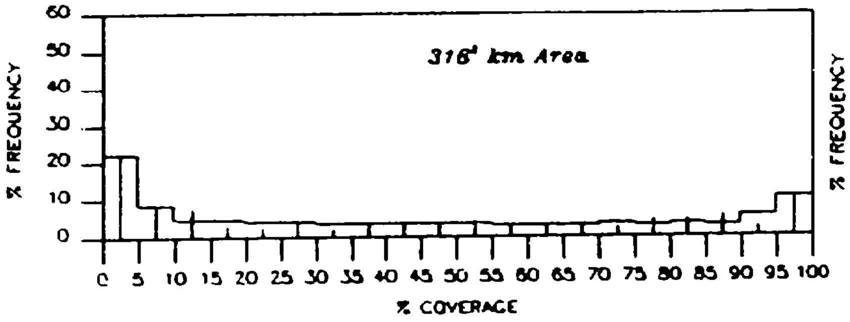
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 6 62 km
Sample size ' = 298 cases

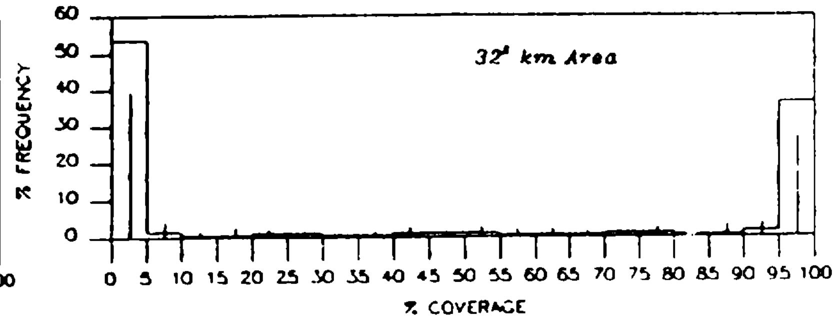
' Computed from Emperical Distributions for 316² Area

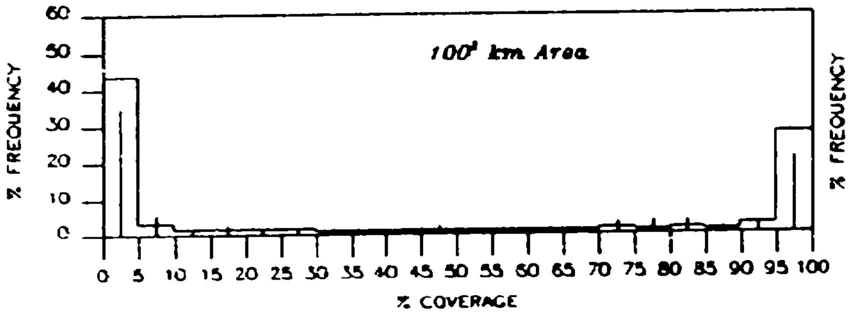
AREAL SKY COVER

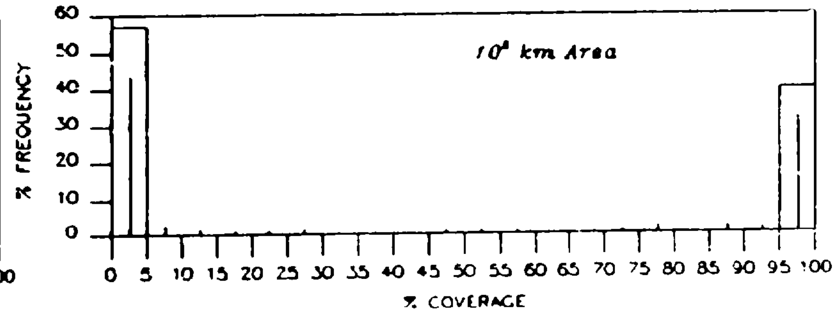
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

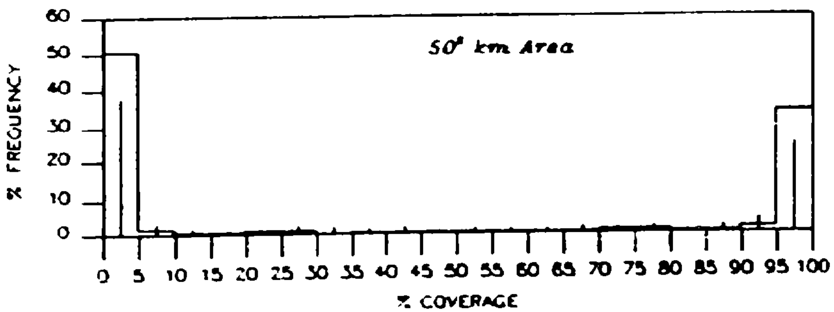
KS 15Z Jun-Aug, 1979-83











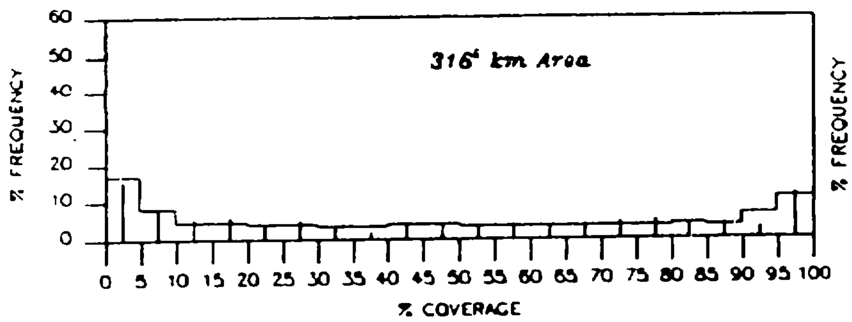
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 6.35 km
Sample size ' = 373 cases

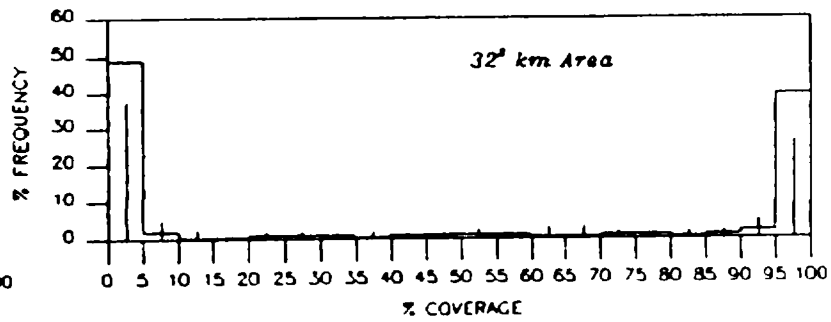
' Computed from Emperical Distributions for 316' Area

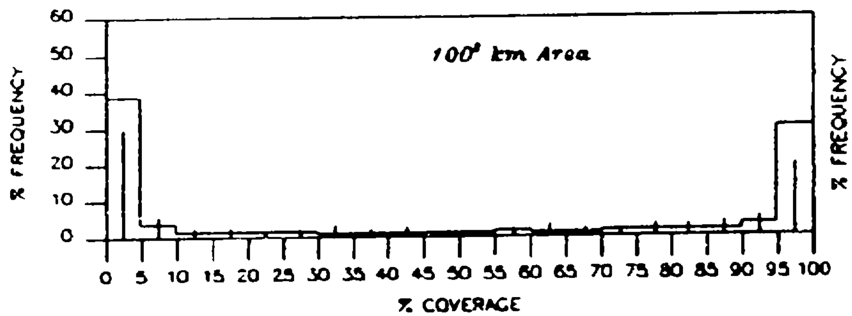
AREAL SKY COVER

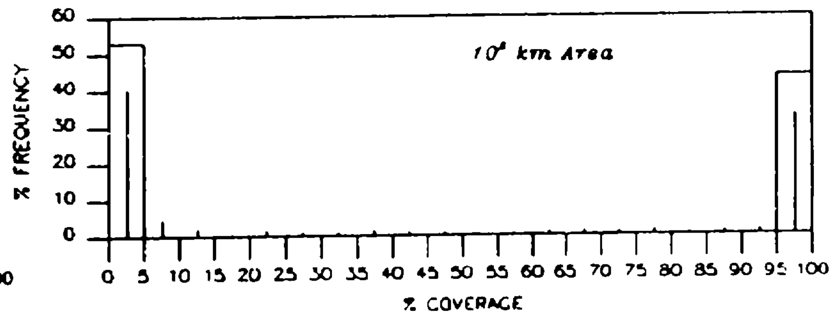
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

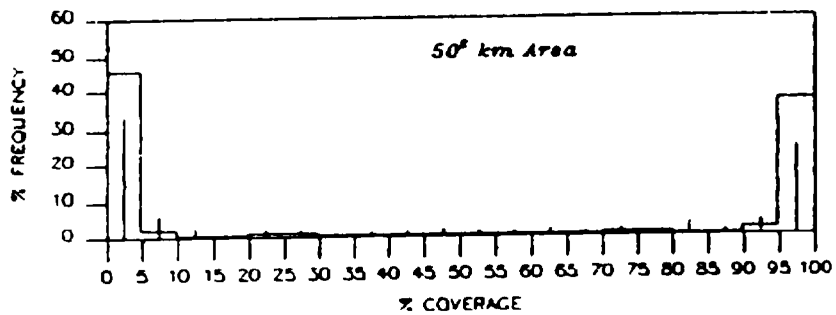
KS 18Z Jun-Aug, 1979-83











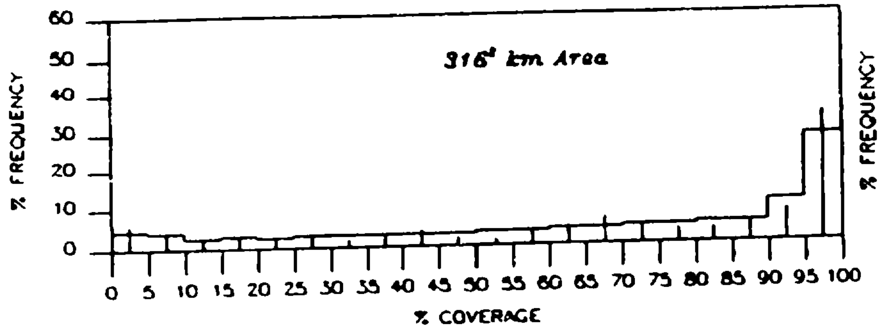
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 5.77 km
Sample size ' = 386 cases

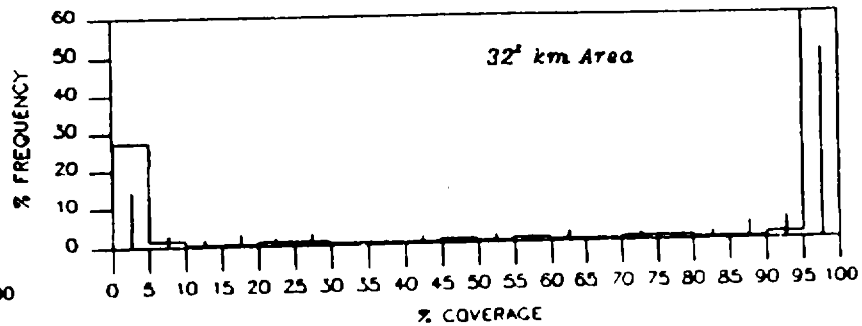
' *Computed from Emperical Distributions for 316' Area*

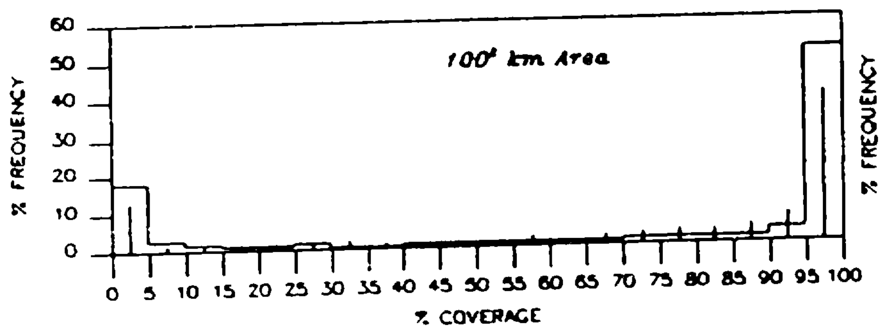
AREAL SKY COVER

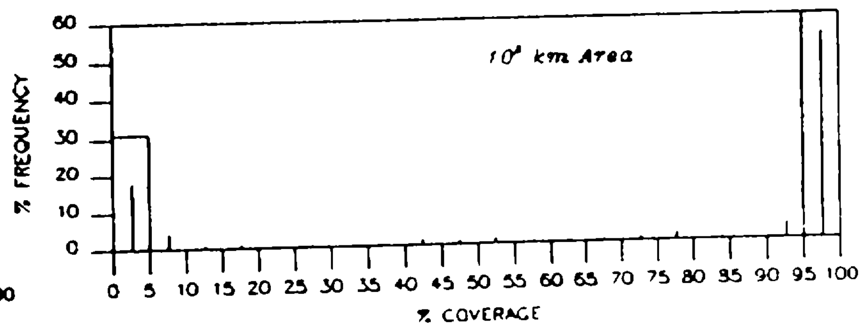
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

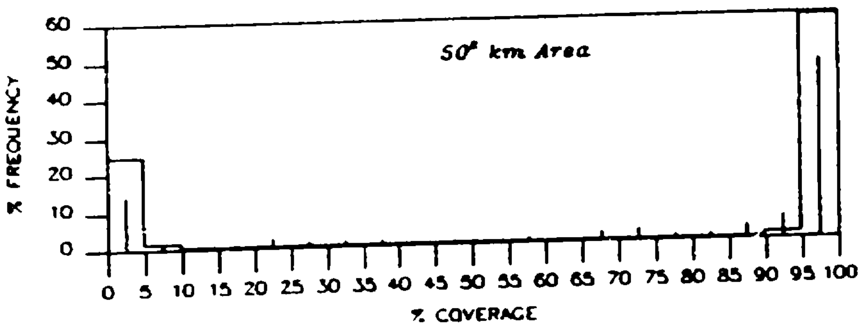
OH 15Z Dec-Feb, 1979-83











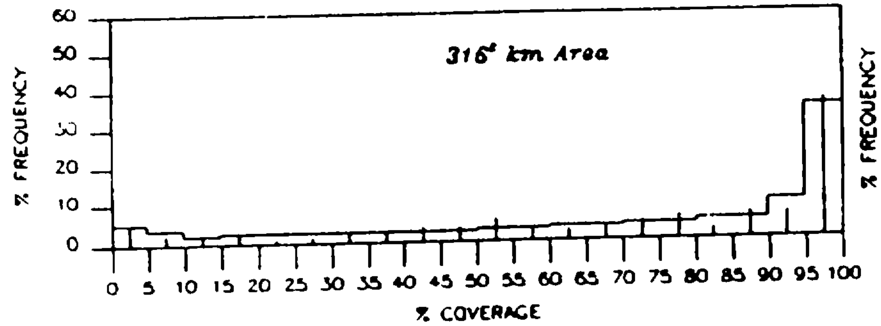
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 5.48 km
Sample size ' = 304 cases

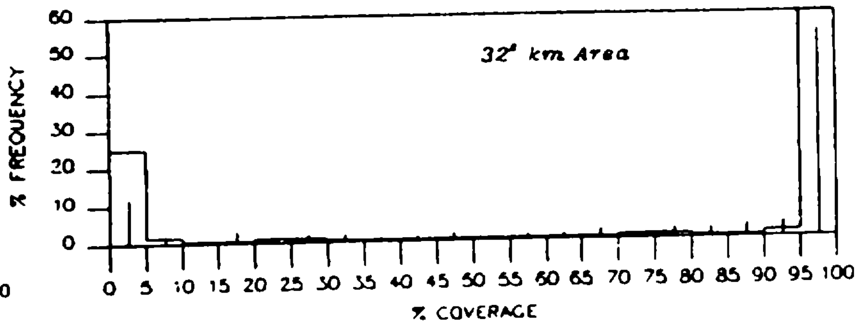
' *Computed from Emperical Distributions for 316² Area*

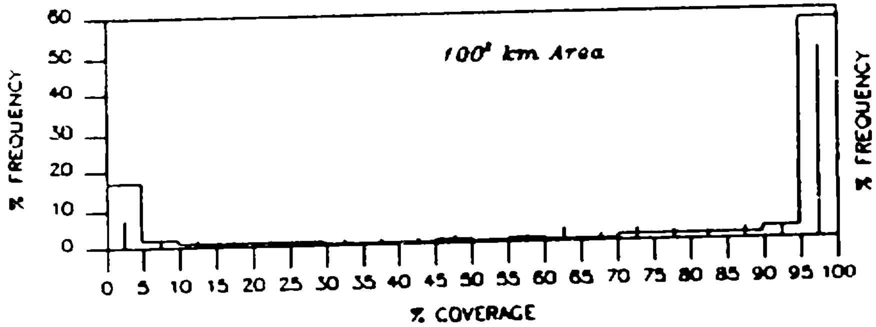
AREAL SKY COVER

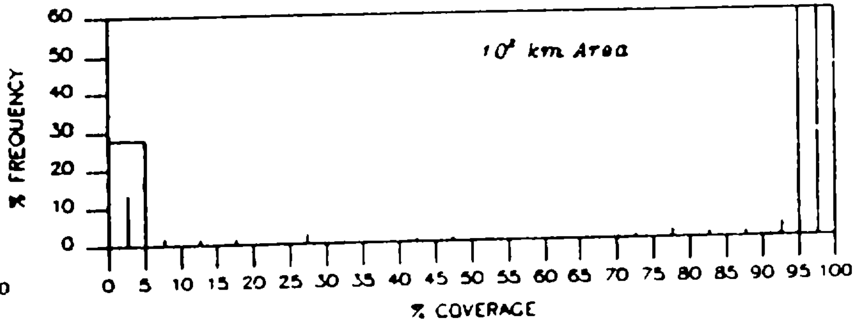
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

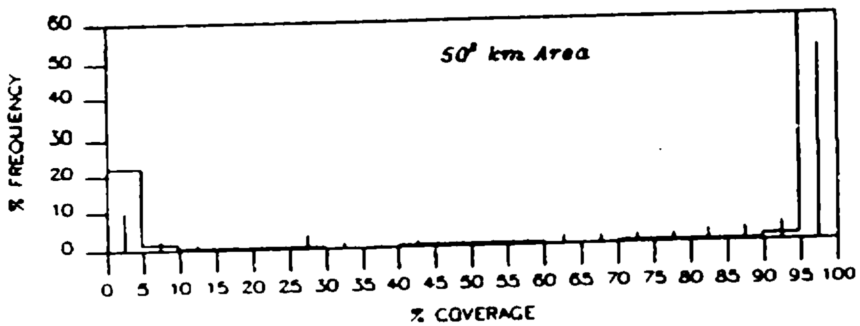
OH 18Z Dec-Feb, 1979-83











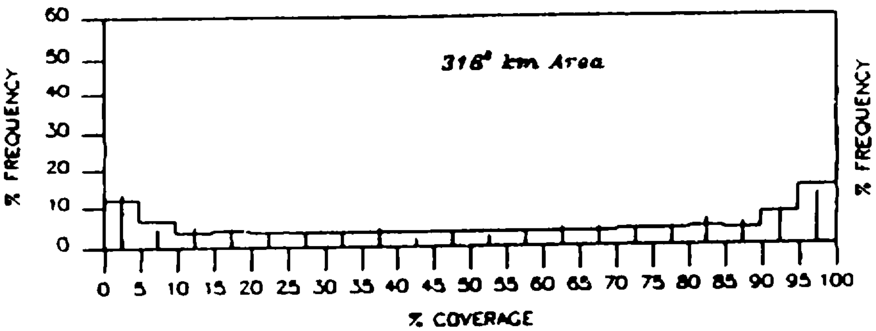
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 6 14 km
Sample size ' = 320 cases

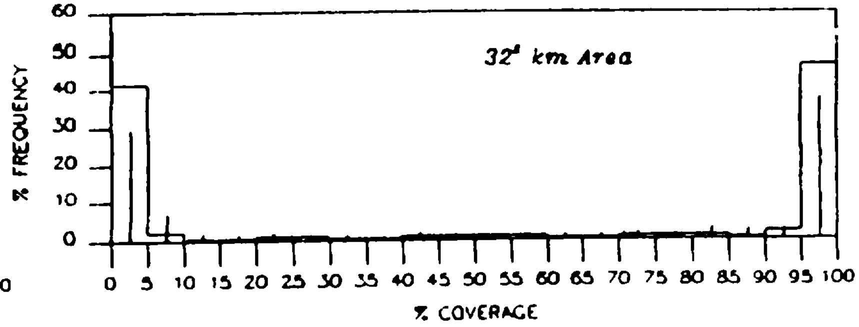
' Computed from Emperical Distributions for 316' Area

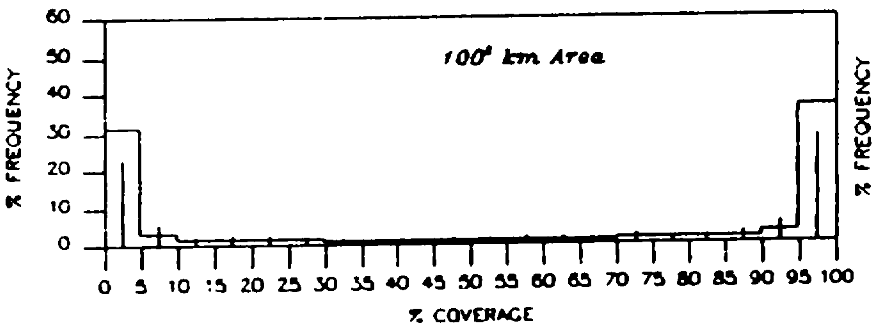
AREAL SKY COVER

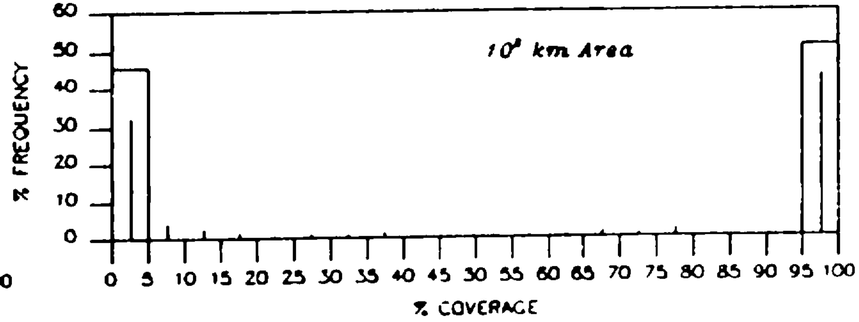
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

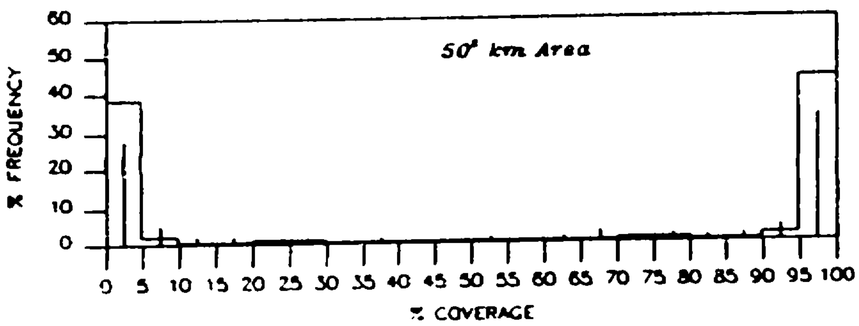
OH 15Z Jun-Aug, 1979-83











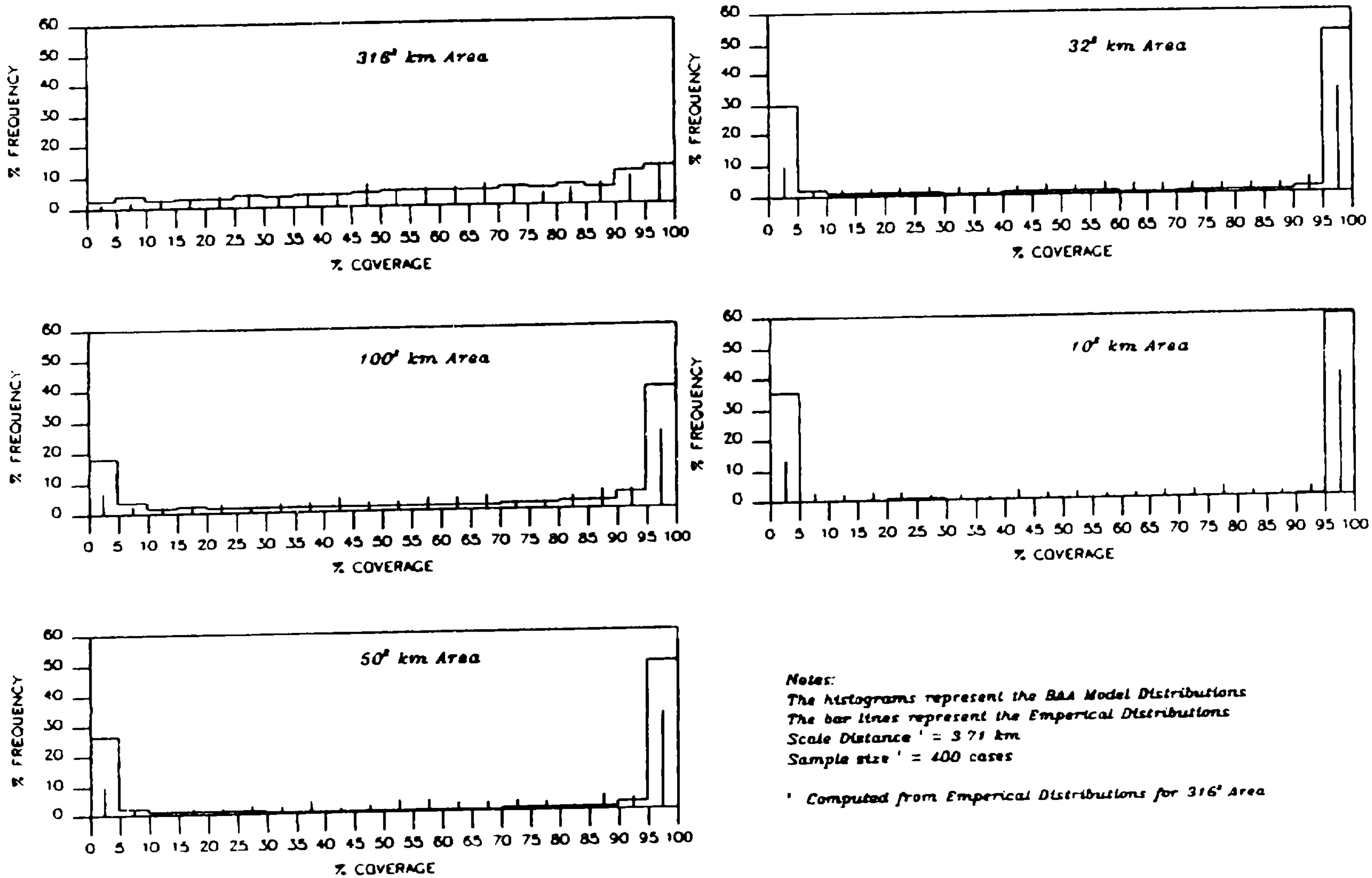
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance [1] = 5.65 km
Sample size [1] = 364 cases

[1] Computed from Emperical Distributions for 316^2 Area

AREAL SKY COVER

Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

OH 18Z Jun-Aug, 1979-83



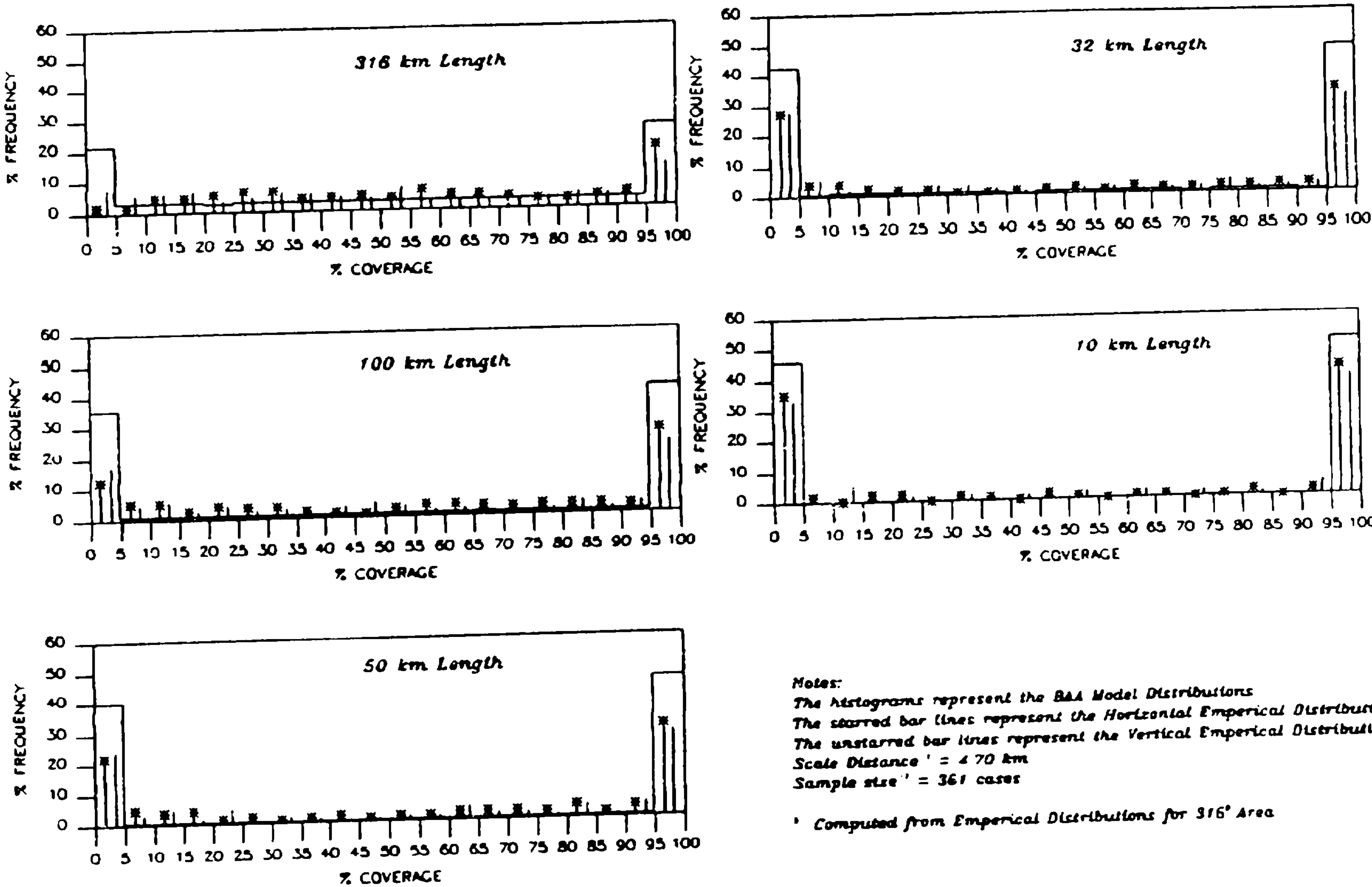
Notes:
The histograms represent the BAA Model Distributions
The bar lines represent the Emperical Distributions
Scale Distance ' = 3.71 km
Sample size ' = 400 cases

' Computed from Emperical Distributions for 316² Area

LINEAL SKY COVER

Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

FL 15Z Dec–Feb, 1979–83



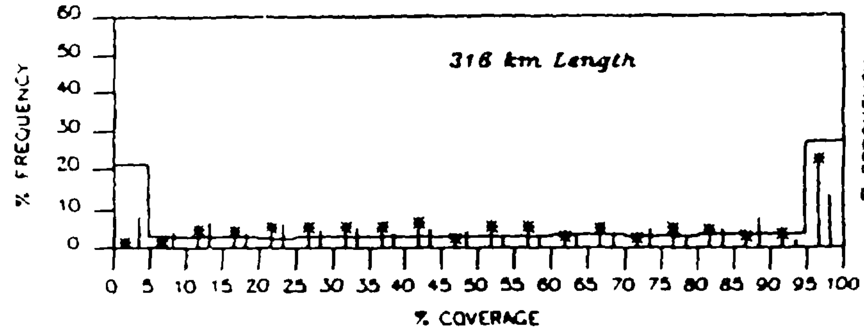
Notes:
The histograms represent the BAA Model Distributions
The starred bar lines represent the Horizontal Emperical Distributions
The unstarred bar lines represent the Vertical Emperical Distributions
Scale Distance ' = 4 70 km
Sample size ' = 361 cases

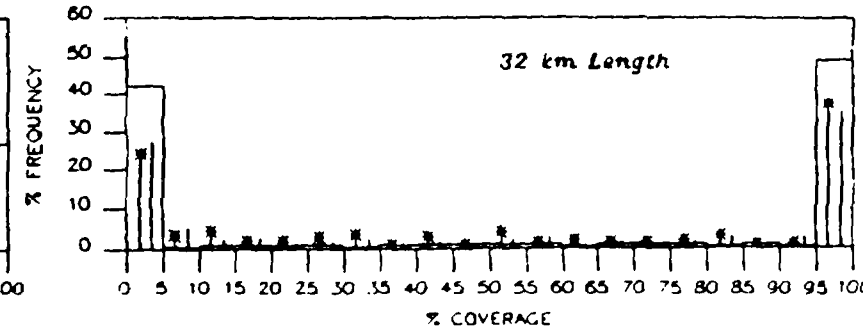
' Computed from Emperical Distributions for 316' Area

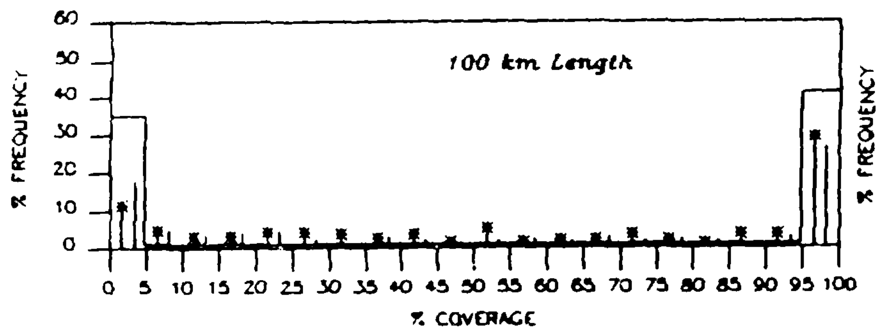
LINEAL SKY COVER

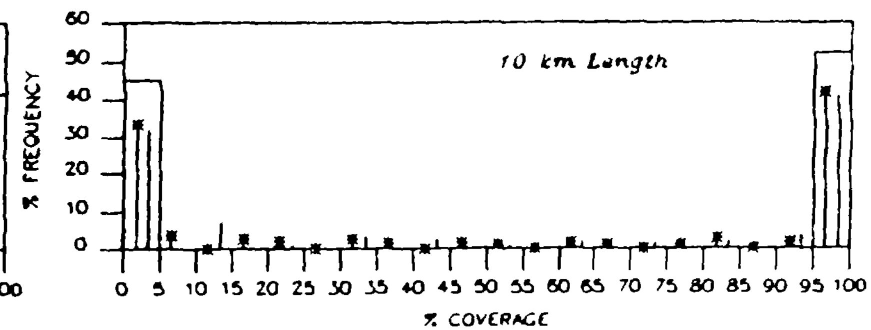
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

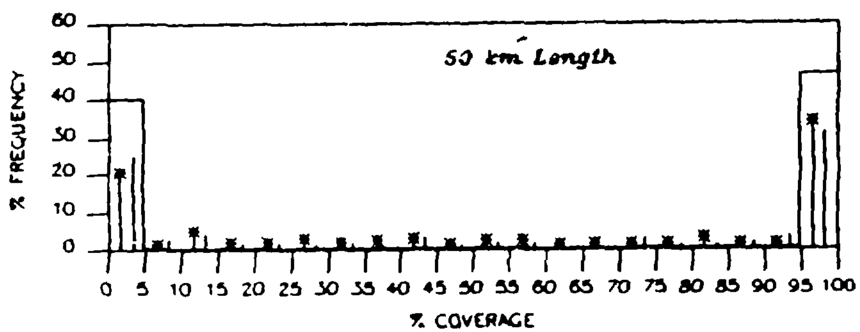
FL 18Z Dec-Feb, 1979-83











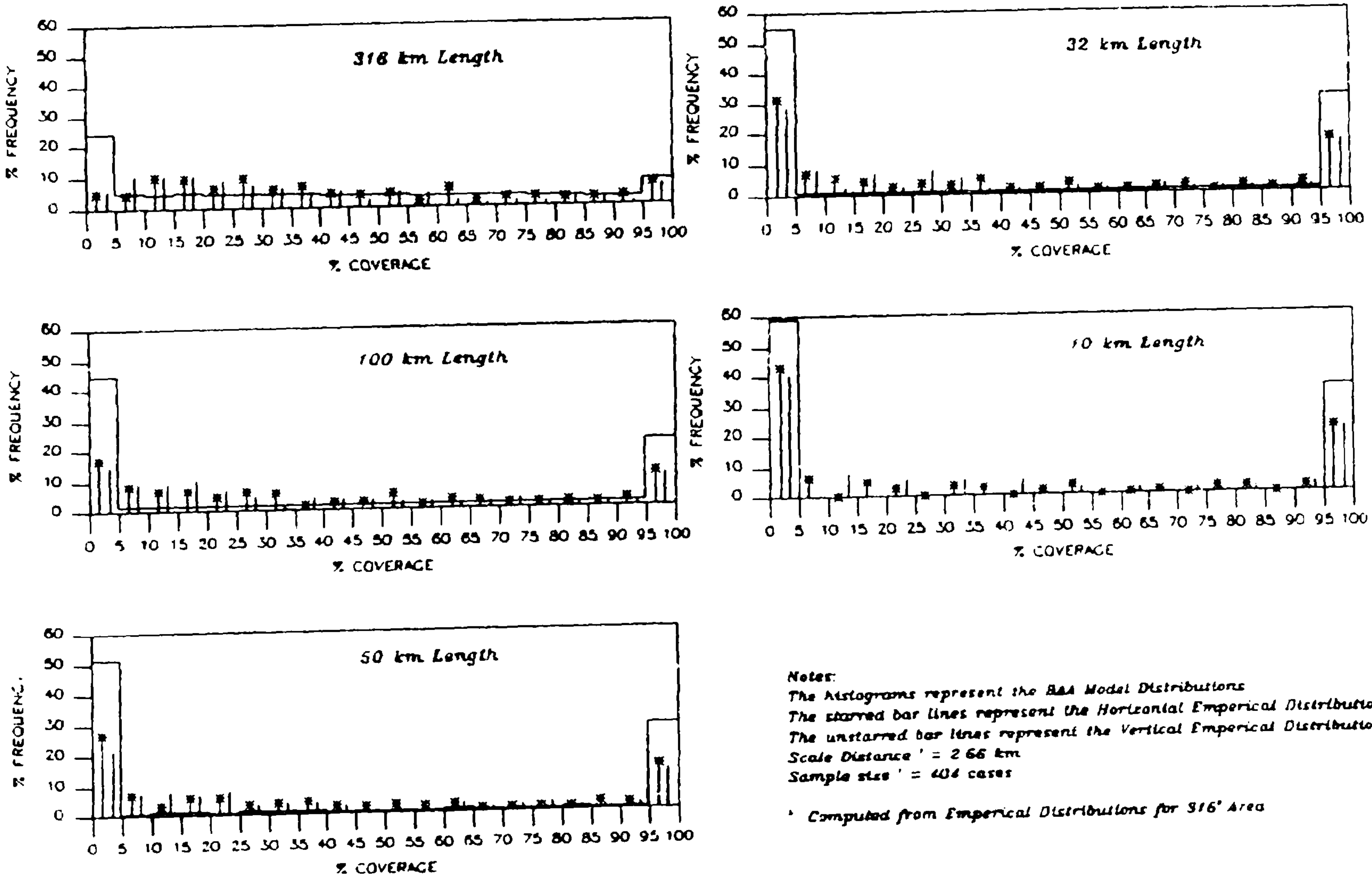
Notes:
The histograms represent the BAA Model Distributions
The starred bar lines represent the Horizontal Emperical Distributions
The unstarred bar lines represent the Vertical Emperical Distributions
Scale Distance ' = 4.61 km
Sample size ' = 357 cases

' Computed from Emperical Distributions for 316' Area

LINEAL SKY COVER

Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

FL 15Z Jun-Aug, 1979-83



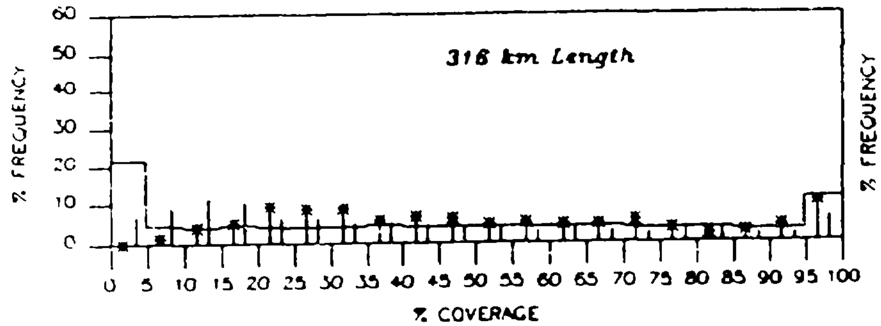
Notes:
The histograms represent the BAA Model Distributions
The starred bar lines represent the Horizontal Emperical Distributions
The unstarred bar lines represent the Vertical Emperical Distributions
Scale Distance ' = 2.66 km
Sample size ' = 404 cases

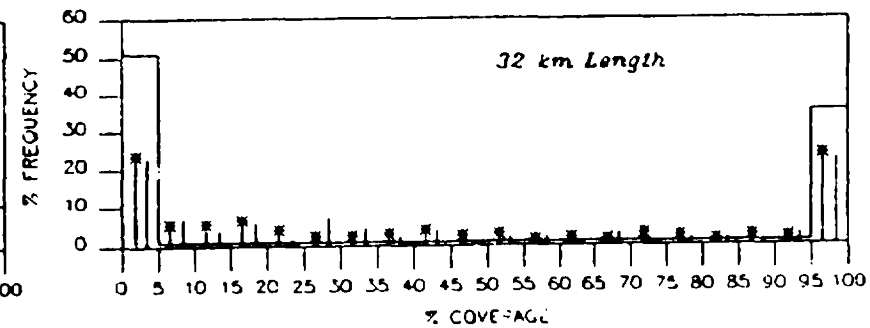
' Computed from Emperical Distributions for 316' Area

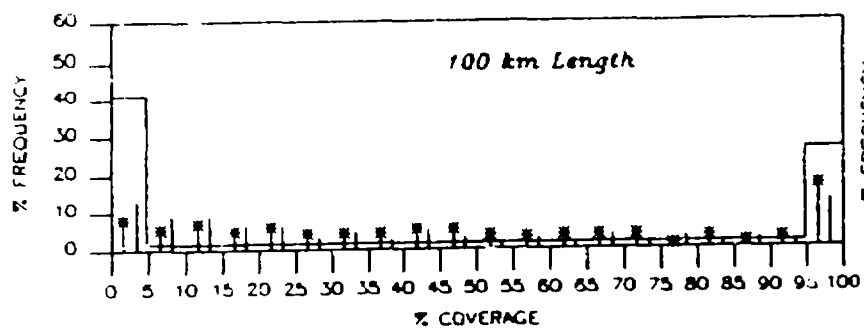
LINEAL SKY COVER

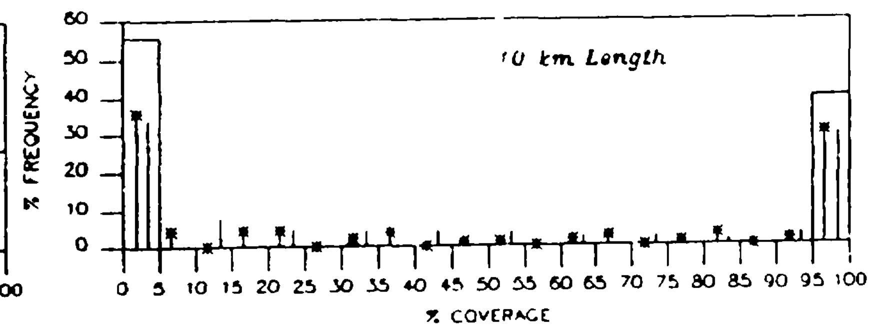
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

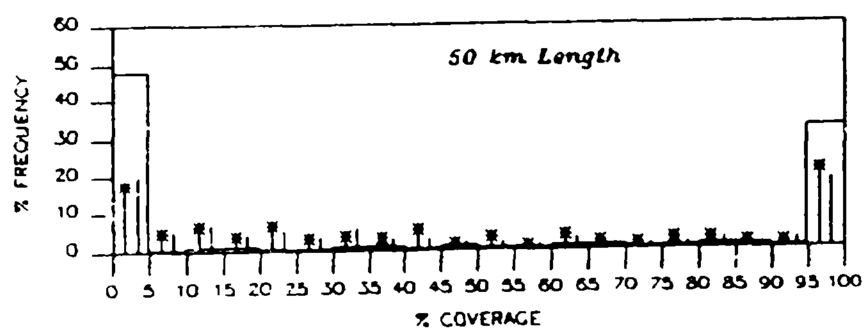
FL 187 Jun-Aug, 1979-83











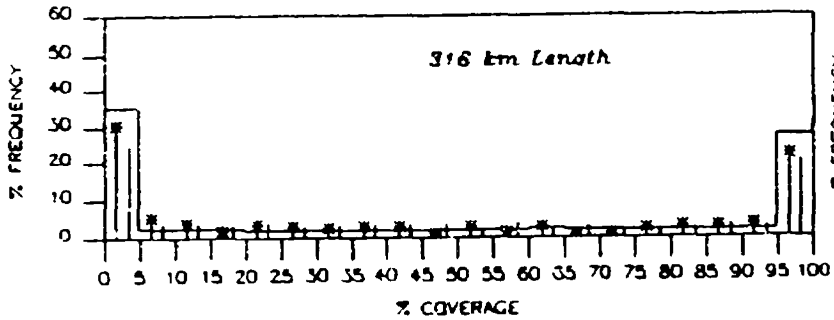
Notes:
The histograms represent the BAA Model Distributions
The starred bar lines represent the Horizontal Emperical Distributions
The unstarred bar lines represent the Vertical Emperical Distributions
*Scale Distance * = 2 80 km*
*Sample size * = 415 cases*

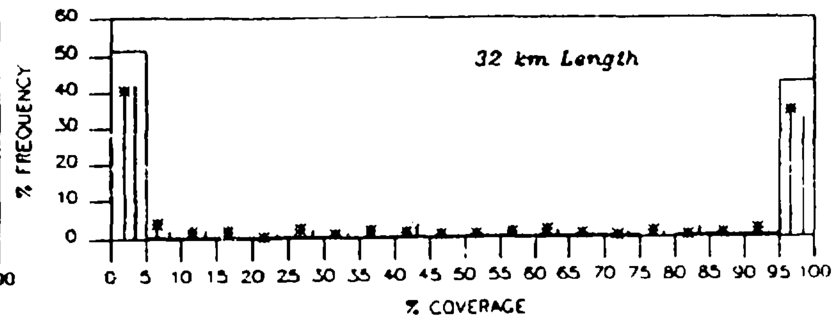
* *Computed from Emperical Distributions for 316* Area*

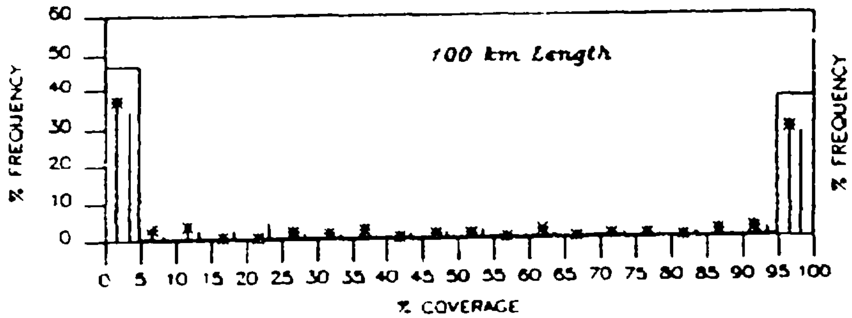
LINEAL SKY COVER

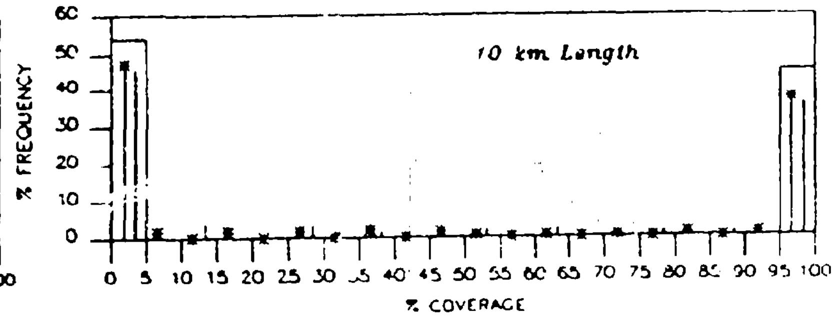
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

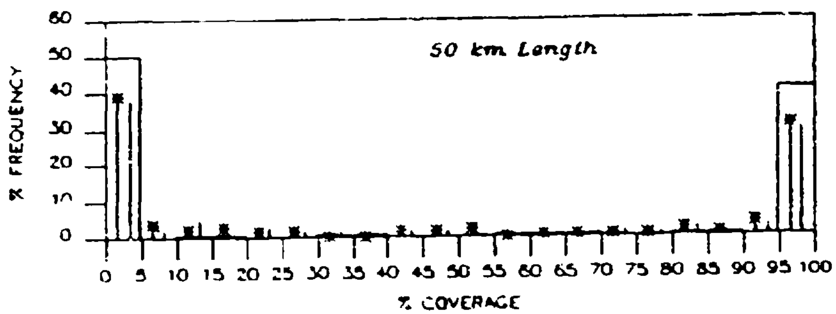
KS 15Z Dec-Feb, 1979-83











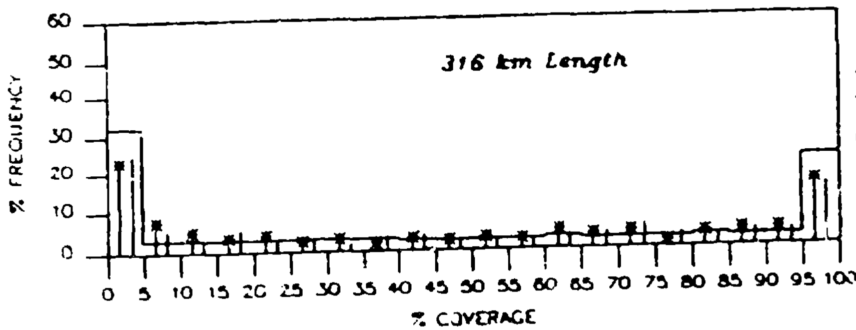
Notes:
The histograms represent the BAA Model Distributions
The starred bar lines represent the Horizontal Emperical Distributions
The unstarred bar lines represent the Vertical Emperical Distributions
Scale Distance ' = 7.37 km
Sample size ' = 300 cases

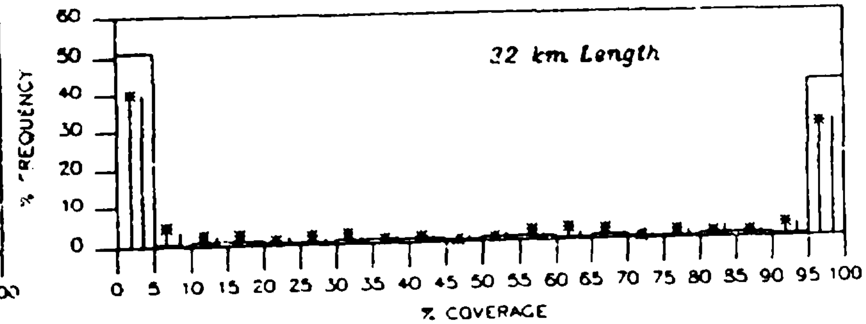
' *Computed from Emperical Distributions for 316' Area*

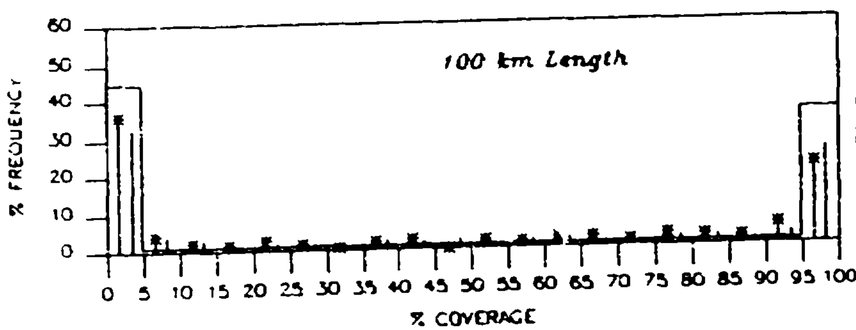
LINEAL SKY COVER

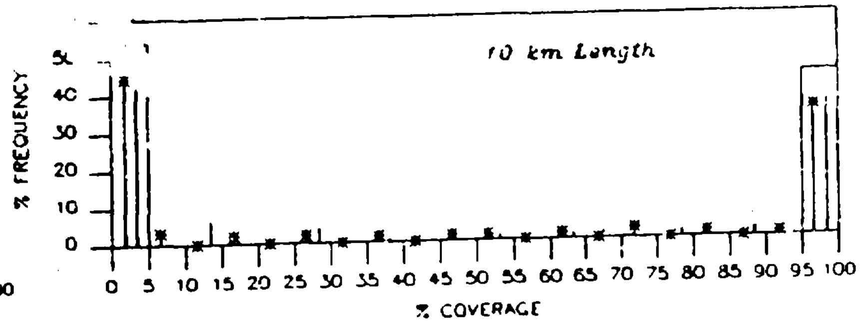
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

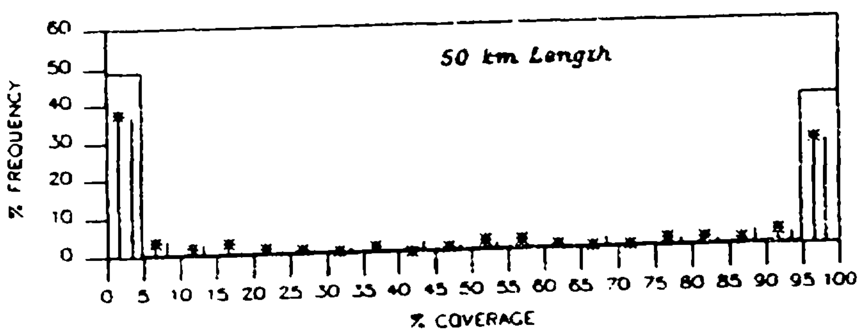
KS 18Z Jun-Aug, 1979-83











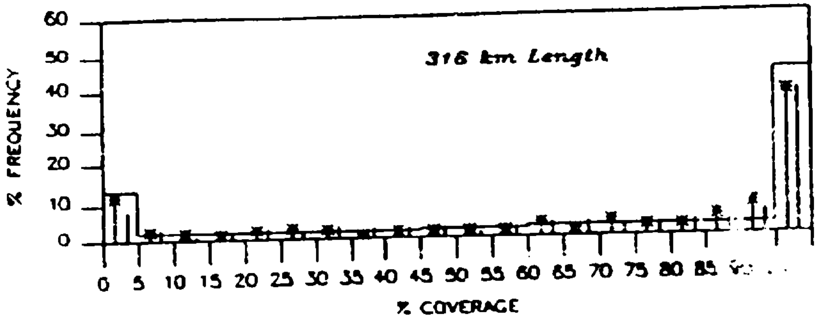
Notes
The histograms represent the BAA Model Distributions
The starred bar lines represent the Horizontal Emperical Distributions
The unstarred bar lines represent the Vertical Emperical Distributions
Scale Distance ' = 5.77 km
Sample size ' = 386 cases

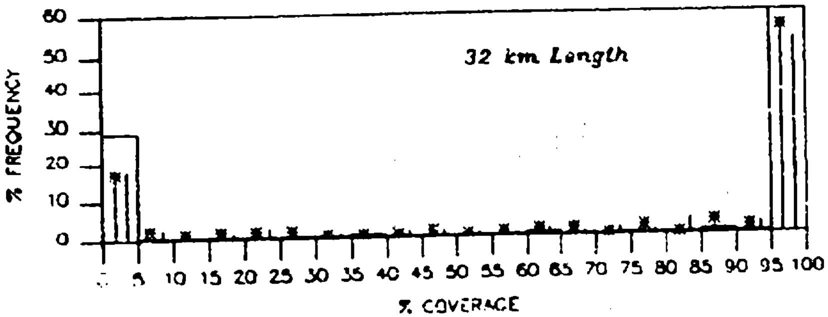
' *Computed from Emperical Distributions for 316' Area*

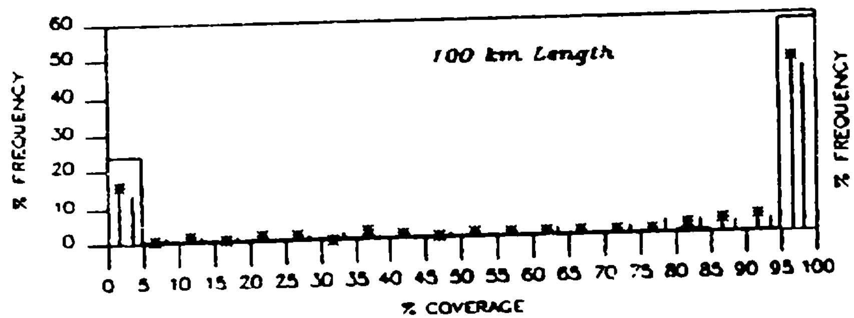
LINEAL SKY COVER

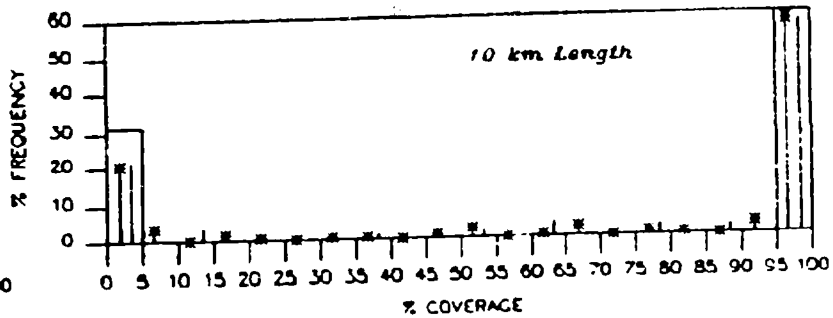
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

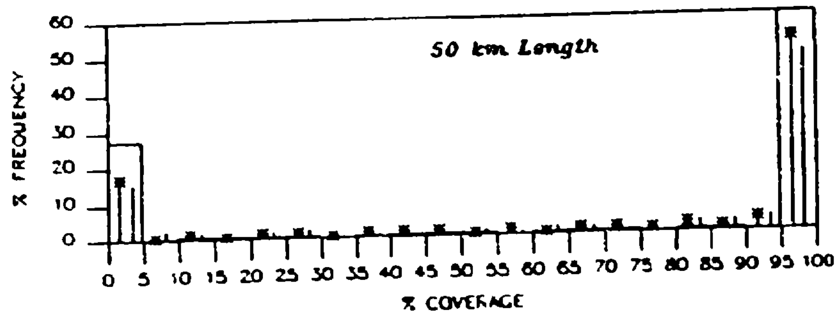
OH 15Z Dec-Feb, 1979-83











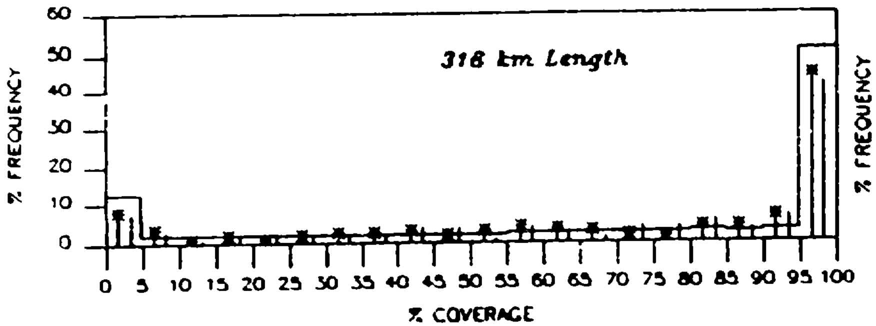
Notes:
The histograms represent the BAA Model Distributions
The starred bar lines represent the Horizontal Emperical Distributions
The unstarred bar lines represent the Vertical Emperical Distributions
Scale Distance ' = 5.48 km
Sample size ' = 304 cases

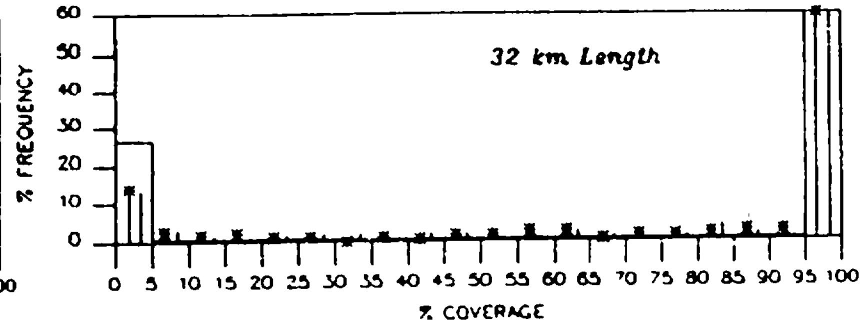
' *Computed from Emperical Distributions for 316' Area*

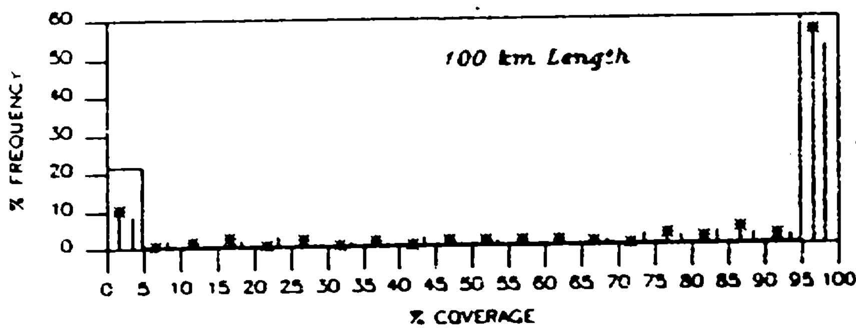
LINEAL SKY COVER

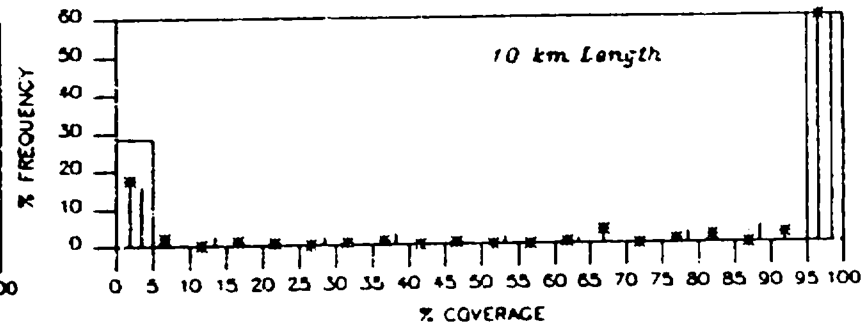
Emperical And Model Distributions [DATA GOES WEST, VISUAL/IR]

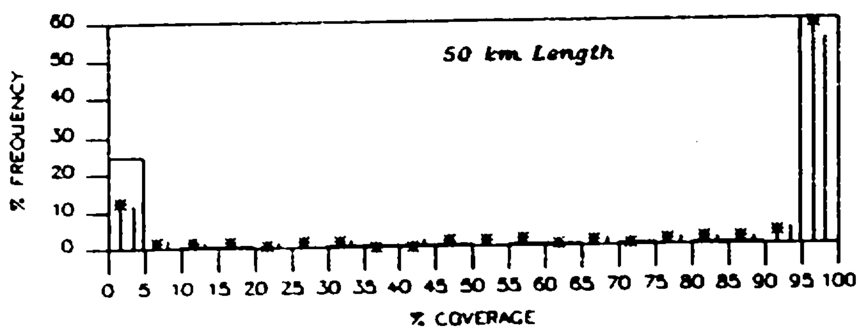
OH 18Z Dec-Feb, 1979-83











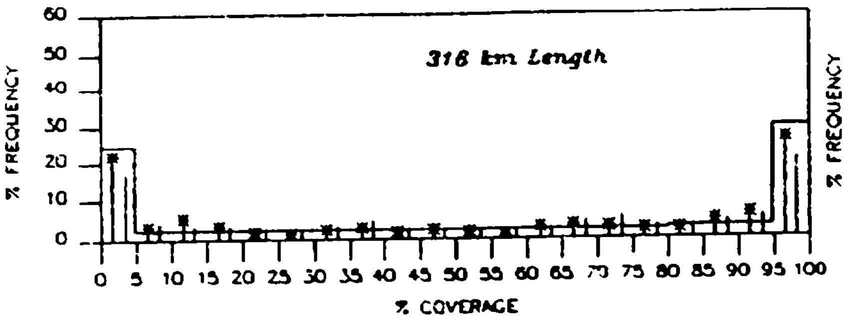
Notes:
The histograms represent the BAA Model Distributions
The starred bar lines represent the Horizontal Emperical Distributions
The unstarred bar lines represent the Vertical Emperical Distributions
Scale Distance ' = 6 14 km
Sample size ' = 320 cases

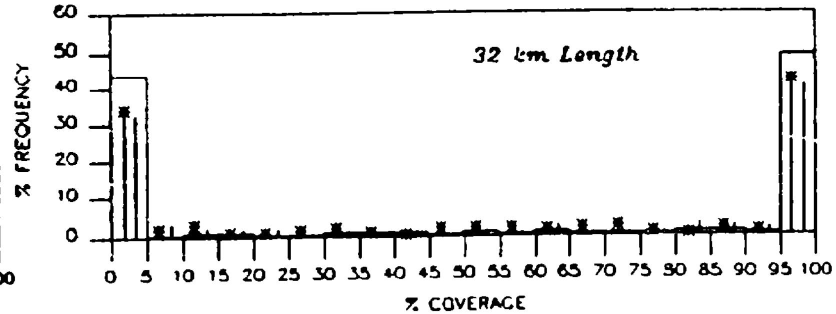
' *Computed from Emperical Distributions for 316' Area*

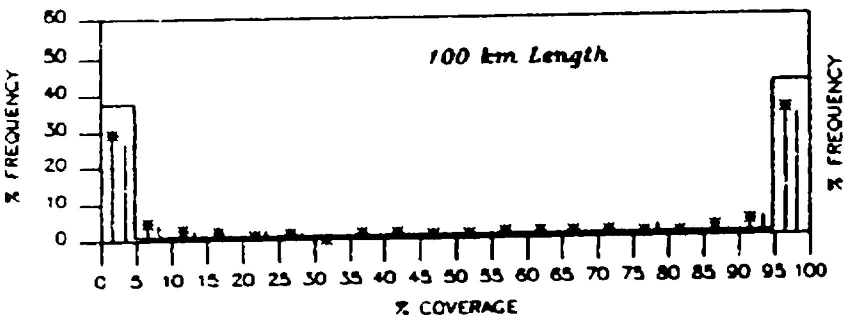
LINEAL SKY COVER

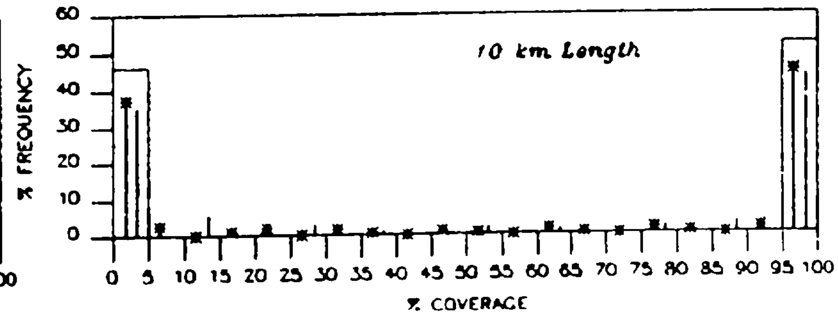
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

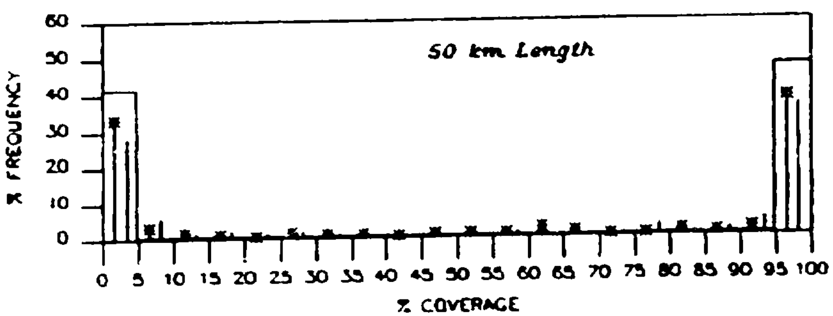
OH 15Z Jun-Aug, 1979-83











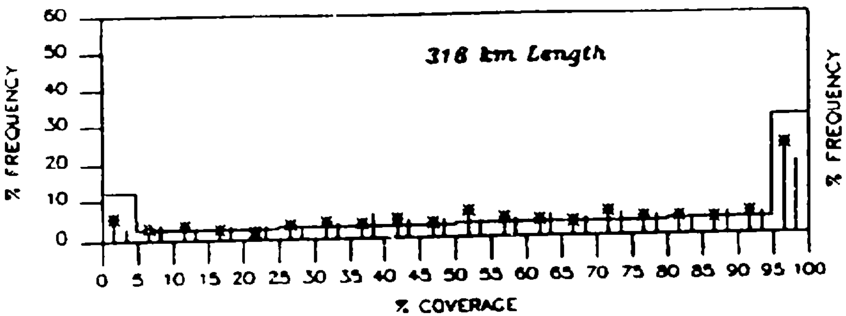
Notes:
The histograms represent the BAA Model Distributions
The starred bar lines represent the Horizontal Emperical Distributions
The unstarred bar lines represent the Vertical Emperical Distributions
Scale Distance ' = 5.65 km
Sample size ' = 364 cases

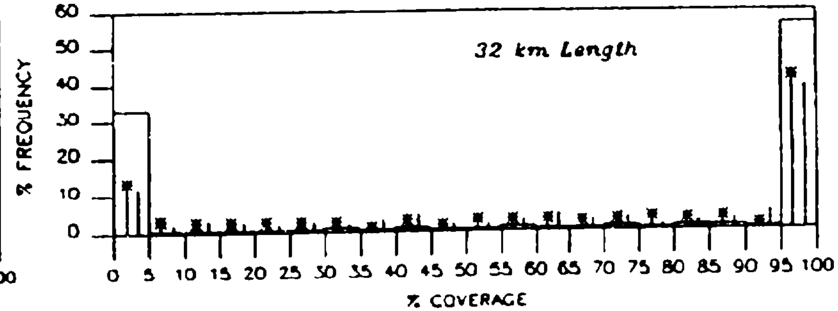
' *Computed from Emperical Distributions for 316' Area*

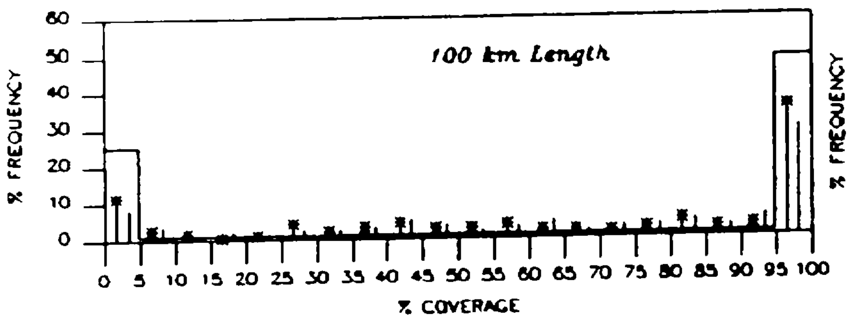
LINEAL SKY COVER

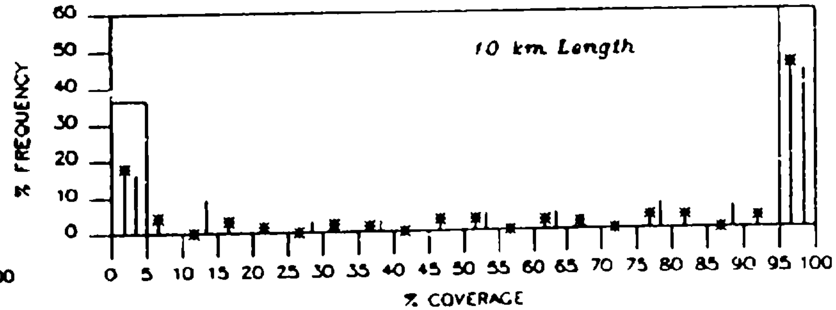
Emperical And Model Distributions [DATA: GOES WEST, VISUAL/IR]

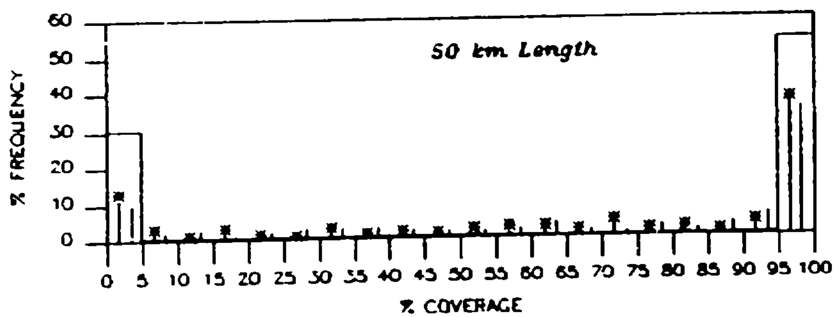
OH 18Z Jun-Aug, 1979-83











Notes:
The histograms represent the BAA Model Distributions
The starred bar lines represent the Horizontal Emperical Distributions
The unstarred bar lines represent the Vertical Emperical Distributions
Scale Distance ' = 3.71 km
Sample size ' = 400 cases

' Computed from Emperical Distributions for 316' Area